THE SCIENTIFIC ATTITUDE

Science is essentially analytical. It can look at any phenomenon, from something as cold and empty as the orientation of a molecule on a surface, to the bearing of a man whose head is bloody but unbowed. But it must get its items separated; anything subjected to its scrutiny must be isolated from the mush of general goings-on in which it is normally embedded; it must be defined, or if it cannot be normally defined, at least one must be able to indicate what exactly is the thing one is talking about and what else is the fortuitous rag-tag-and-bob-tail that happens to be cluttering up at the moment."

—C. J. WADDINGTON

"*The Life and Soul of Science is its practical application.*"

—LORD KELVIN

SUGARCANE CULTIVATION

SUGARCANE CULTIVATION

(Practical Suggestions for Sugarcane Plantations)

BY

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and Drainage"

WITH A FOREWORD BY

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FOREWORD

I HAVE great pleasure in writing a Foreword to this book which is an attempt by a student-colleague of mine to record for the benefit of sugarcane growers in our country his *practical experiences* in growing this crop on a *plantation scale.*

On date the resusciated sugar industry of India is kept on its legs by a handsome tariff protection which has been fully justified by the great benefits which the industry has conferred on all sections of our people—the labourer (both in field and factory), the agriculturist, the technician, the educated and the uneducated unemployed and last but not the least our business men. The need, however, to place this industry in a position where it can stand competition with the other cane countries of the world is necessary and is becoming increasingly urgent from the trend of world events. To achieve this it is essential that the cost of raw material—that is the crop—should be considerably lowered from what it is at present. These costs are to-day relatively high in our country, either because of low acre-yields in sub-tropical India or because of the higher costs of growing in tropical India.

For lowering cost of raw material the growing of the crop on a plantation scale is a necessity, because it is only thus that the crop can be given the benefits of the labour-saving and money-saving advances in agricultural practices. Such growing of the crop on plantation scale is a recent development following the expansion of cane area and increased attention to it as the result of tariff protection; it is at present confined only to a few

provinces and Indian States. The chief value and utility of Mr. Gururaja Rao's book lie in the record of practical recommendations for sugarcane plantations contained in it. It has to be particularly noted that the recommendations made are *not* on theoretical considerations or from results of small-scale plots—done to death by an elaborate application of statistical methods—as we have been sometimes accustomed to in the past. The recommendations in this book are based on the actual experiences of the author in the growing of large-scale plantations with all their *difficulties, limitations and advantages.* The book should thus prove useful as a practical guide to other sugarcane estate managers in the country.

For obvious reasons the author is at his best in the more important part of the book (Part II) and entitled "Practical Suggestions for Sugarcane Plantations".

T. S. VENKATRAMAN.

Camp: Thyagarayanagar,
MADRAS,
10*th September* 1946.

PREFACE

I HAVE endeavoured, in this treatise, to present to the sugarcane grower the theoretical foundations and the practice of growing sugarcane. The recommendations are based on my intimate field and crop experience of more than twenty-five years in growing sugarcane on a large scale: first on the then largest Government Experimental Farm, Hiriyur, for over twelve years and then on sugar factory farms in Mysore and Bhopal States. The period includes one of intense and successful application of this experience in growing cane under the parental and able guidance of Dr. Leslie C. Coleman, M.A., Ph.D., C.I.E., the then Director of Agriculture in Mysore and the first Managing Director of the Mysore Sugar Co., Ltd. The sugarcane was grown for this 1,400-ton factory on planned scale and under scientific control on Government waste lands and also under supervision by the cultivators over 12,000 acres, on land brought under cultivation for the first time under one of the largest irrigation schemes in the world: The "Krishnaraja Sagara" near Mysore. The period includes also a similar successful work in the State of Bhopal, C.I., for about three years. In this difficult work I had the good fortune of having had the unstinted support of Sir Joseph W. Bhore, K.C.S.I., I.C.S., Ex-Member of the Viceroy's Executive Council and the present Prime Minister of Bhopal State, and enjoyed, in addition, the Royal patronage of H. H. the Nawab of Bhopal. To all these I am profoundly grateful.

I am glad to be able to assure the reader, with confidence, that in this book I am not giving any prescriptions which I have not found in practical application advantageous and in theory sound. This goal has

ruled out any attempt at description of all cultivation methods in vogue in growing sugarcane over areas and under conditions existing outside the influence of the factories in Mysore and Bhopal States, as such a step, I felt, would be unhelpful and might even cloud the important recommendations found best. I have taken pains to partly atone for this deliberate lapse, in Part I of the book, by presenting, in general, the available important theoretical speculations, which provide the linchpin to the accelarating and upward trend of cultivation standards aimed for higher yields, and of better quality of sugarcane under pressure of the exacting needs of the modern sugar factories. These theories being of universal application should prove ever potent in changing cultural methods, wherever called for.

Part II of the manual provides with practical instructions where valuable results of research have been integrated to influence methods of cultivation to produce sugarcane crops of maximum yields in tonnage and of maximum sugar content. The drawings and photographs will, I am sure, be of help in understanding the text.

In the Appendices the reader will find valuable information connected with the subject.

It is my duty to express my feelings of deep gratitude to Rao Bahadur Sir T. S. Venkatraman, KT., C.I.E., D.SC., for having readily consented to go through the typescript and for having, with great kindness, written the Foreword in the midst of other more pressing engagements.

K. M. GURURAJA RAO.

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PART I

PRINCIPLES OF CULTIVATION OF SUGARCANE

CHAPTER I

HISTORY OF SUGARCANE

THE sugarcane belongs to the order of grasses and is perennial in its habit. Mention of sugarcane is made in Atharva Veda: the fourth period of the Vedas of the pre-historic Hindu lore. Its original home is traced by economic botanists to Eastern Asia. Sugarcane, in recorded history, is mentioned to have been paid as a tribute to the Emperor of China from provinces of the Indian border. It seems to have spread east, about 424 A.D., into southern China, on to Java, Philippines and islands of the Pacific, Hawaii, etc. It is said to have travelled towards the west into Arabia, the Levant and along the Mediterranean Coast, to Southern Spain, by about 1520 A.D. Its cultivation is known to have extended to Brazil, Peru and other South American Republics and the islands of the Atlantic by 1650 A.D. By eighteenth century its spread was almost global, being found under cultivation not only in the whole of the tropics, but also in countries exposed to night frosts, which shows its extraordinary powers of adaptation.

DISTRIBUTION OF CANE AREAS

Sugarcane is grown roughly between North latitude 32° and South latitude 30°. The countries included are:— India, Straits Settlements, Cochin China, China, Japan, Formosa, Philippines, and Java in Asia; Spain and countries along the Mediterranean Coast in Europe; countries around the Gulf of Mexico as Lousiana, Texas, Florida, Georgia, Mexico, Cuba, Sandomingo, Portorico, British West Indies consisting of Barbados, Trinidad,

Jamaica, Leeward Islands and French Antilles in North America; Guatemala, Honduras, British Honduras, Nicaragua, Costorica and Panama in Central America; Colombia, Venezuela, British Guiana, Dutch Guiana, Equador, Peru, Bolivia, Brazil, Argentina and Paraguay in South America; Madeira, Canary Islands, Angora, Liberia, Egypt, Mozambique, Natal, Mauritius, Reunion in Africa; and Hawaii and Tahiti in Australasia.

The soil, climate and economic conditions naturally differ to such a great extent due to vast geographical distribution that it is impossible to bring out within the compass of a book, any one method of cultivation of sugarcane that can be followed as the most profitable under all conditions. In portions of Bihar in Northern India, sugarcane is grown almost entirely without irrigation at the lowest cost of production, while, we have, at the other end, as in Java, its cultivation being raised to the status of horticulture, giving the heaviest crop-yields of the best quality.

Renaissance of the Indian Sugar Industry and its Influence on Improvement of Sugarcane

The sugarcane, during the period before protection, played an important *role* in India as an industrial crop, though its cultivation was at a low level of the resourceless peasant-farmer. It was grown essentially to produce *Gur* or *Jaggery*, the main article of consumption of the masses. Even now 60% of the sugarcane grown in India is used for making *Gur*, only about 20% being used for making white sugar by the factories.

The demand for protection for the Sugar Industry in India was raised about fifty years ago, when European bounty-fed sugar began to menace the old sugar producing countries of the world. The needs of the Indian

Sugar Industry for protection was recognised only in October 1929, when the Imperial Council of Agricultural Research (I.C.A.R.) on the recommendation of its Sugar Sub-Committee urged upon the Government, the necessity to institute a Tariff Board enquiry into the question of protection.

The interest of the Government of India as regards the best method of exploiting the advantages which India possessed in respect of sugarcane may be said to have begun in February 1919, when Mr. Wynne Sayer of the Indian Agricultural Service was appointed to compile all relevant data on the subject of Sugarcane Industry. In the year 1920 the Indian Sugar Committee appointed by the Governor-General-in-Council, after an itinerary of all the important places in India and the famous sugar producing island of Java, submitted its comprehensive report, laying great stress on the importance of sugar, whose consumption was gradually rising in the national economy of India.

The great part the I.C.A.R. played in the renaissance of the sugarcane industry should be noted in brief. Its establishment marks an important mile-stone in the march of agricultural improvement in India. The Sugarcane Sub-Committee of the I.C.A.R., which was entrusted to examine and report on measures necessary for the development of Sugarcane Industry in India, in its meeting in October 1929, recommended to institute a Tariff Board to go into the question whether protection should be given to the Indian Sugarcane Industry. The Council accepted the recommendation and were successful in inducing the Government of India to order a Tariff Board enquiry to find out whether protection was necessary, and if so in what measure, to help the Industry. As a result, the Government of India passed "The Sugar

Industry (Protection) Act" in the year 1932—an Act "to provide for the fostering and development of the Sugar Industry in British India".

The biggest single achievement, in addition to protective duty, that influenced the phenomenal and rapid expansion of the sugar industry from the working of only 32 sugar factories in the year 1931–32 to 150 factories in the year 1945–46, was the splendid work done in sugarcane breeding in the Central Sugarcane Research Station, Coimbatore, under Rao Bahadur Sir T. S. Venkatraman. This provided the Industry with varieties of sugarcane of a higher yielding capacity and a greater sugar content under varying cultural, climatic and economic conditions.

The influence of these factors on the sugarcane industry is seen at present in the following:—

1. The area under Coimbatore and other improved canes had risen from 8 lakhs of acres in 1930 to 30 lakhs of acres in 1937.
2. Total area under sugarcane has risen from 29 lakhs of acres in 1930 to 44 lakhs in 1945–46.
3. Over 82% of the total area under cane is occupied by the improved canes.
4. Price paid for cane to the cultivators by the factories has increased from Rs. 1,77,50,000 in 1931–32 to Rs. 18 crores in 1939–40 and to Rs. 22 crores in 1945–46. To this must be added the income augmented by research-results in cane of about Rs. 2,50,00,000 per year.
5. The Sugar Industry represents the second largest in India with an investment of Rs. 32 crores, first place being held by Textiles.

6. The Sugar Industry finds employment for 3,000 university men, graduates in Science, Engineering, Arts and Commerce, one lakh unskilled workers and twenty million cultivators.
7. The value of sugar and *Gur* produced works to about Rs. 75 crores per year.

CHAPTER II

THE SUGARCANE PLANT

It is beside the purpose of this book to give a detailed description, in scientific terms, of the botanical characters of the sugarcane plant. However a general description* of the plant is attempted to enable the reader to understand the various factors that influence planting, growth, and practice of cultivation of the sugarcane crop recommended in Part II of the book.

Characters of the Plant

The sugarcane plant consists of its roots and root-stock, the stalk, the leaf, and the inflorescence. A general description of the structure and function of these are given.

The root system of the sugarcane.—The roots of the sugarcane grow from the nodes of the stem: from the root zone *r* (Fig. 1 A). They are fibrous, lateral and very delicate. They ramify in all directions and generally extend to a distance of two to three feet from the stem. They are not known, under irrigation conditions, to penetrate the soil very deeply. The depth to which they penetrate depends largely on the nature of the soil, extending furthest, in light open soils. In badly drained and stiff soils they are very superficial and may be seen to turn upwards to the surface for air (Oxygen). The cane has no tap root (Fig. 1 B) and the root-hold in the soil is comparatively weak.

As with other plants the function of the roots is two-fold:

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* Description generally follows Noel Deerr in cane sugar.

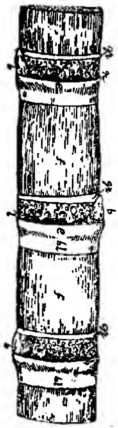

FIG. 1 A
(after Noel Deerr)

FIG. 1 B
(after Quintus)

FIG. 1 A. Sugarcane set with three eyes or buds
f. Joint or internode
e. Node or joining place of internodes
b. Eye or bud, which sproutes and grows into a cane plant
r. Root zone from which roots take their rise.

B. A sprouting or germinating one-eye set with a young sprout and roots. Note there is no tap-root.

First is their mechanical hold on the soil. The root hairs closely envelop the particles of soil maintaining their hold on the soil;

Secondly, the root hairs absorb water and plant food from the soil and transmit them to the other parts of the growing cane.

The stalk.—This is made up of a series of joints or internodes *f* (Fig. 1 A), separated from each other by the nodes *e*. Generally the internodes grow in a continuous line, but occasionally they are more or less zig-zag. The stalk of the cane is roughly cylindrical and in some varieties is swollen between the joints giving the internodes a barrel shape. The internodes may, depending on the variety, be cylindrical, conical, biconcave, etc. The length and diameter of the internode depend on the variety and within the variety, on the conditions of growth, such as leaf development, drought or cold weather, soil conditions, disease and maturity of the joint. The smallest diameter is found in reed canes and the greatest in elephant cane, a variety which is not grown commercially. The length of the stalk, under most favourable conditions, is found to attain as much as 25–30 feet but 12 feet may be taken as an average for a well grown cane. Growth studies have proved, without doubt, that there is a definite pronounced periodicity of growth. In such periods as during very favourable conditions of growth, the optimum is exceeded and the curve of the "Grand Period" shoots up.

The stalk of sugarcane does not increase in thickness after primary thickness is reached, or in other words there is no secondary growth in thickness.

At each node, and alternately at opposite sides, is the eye or bud *b* (Fig. 1 A), cane in embryo. The size of the bud and its shape depend on the variety of cane. In size it may be that of a pea or slightly larger, and in shape may be triangular, pointed, oval or hemispherical. In some varieties the eye is swollen and prominent.

There is a well marked channel running upwards from the eye in the stalk but this may tend to disappear in some varieties.

There are from one to three rings of semi-opaque whitish spots immediately above each joint. This is the zone of adventitious roots *r* (Fig. 1 A), each spot being an embryonic root. There is the bloom band shown at *bl*, the leaf scar at *l* and the growth ring at *gr*. The last is a narrow region of meristematic tissue, fairly prominent and of value in identification of varieties. It plays also an important part in the subsequent growth of the cane.

Propagation is asexual. On planting, an eye or bud of the cane sprouts and a single stalk is formed known as the mother stalk (Fig. 1 B). The underground portion of the stalk forms a rhizome, containing at each node a dormant eye. As growth proceeds new shoots, known as tillers, are produced from this rhizome until the whole stool is formed. On cutting down the stalks at harvest the underground portion of the plant is stimulated to throw out shoots from the dormant eyes, which go to form the first ratoon crop.

Canes are found in colours of green, yellow and in shades of red: pink to deep purple. In striped canes colouring matter is found to run in streaks running lengthwise with the stalks. From the striped canes self-coloured sports frequently occur.

The stalk consists roughly of a hard outer rind and a mass of softer tissue in the interior interspersed with fibres, the latter being more frequent about the periphery of the stalk. The rind is made up of a thick epidermis with a strong outer cuticle, often with a thick layer of wax outside, impervious to water, and a layer of thick walled cells (Collenchyma). The function

of the cuticle is to prevent evaporation of water from the stem of the cane and to protect the softer interior parts from mechanical injuries; the layer of thick-walled cells gives rigidity and strength to the stem. These thick-walled cells gradually pass into the thin-walled cells of the ground tissue or parenchyma, which serve to store up the sweet juice of the cane. The fibres are known as fibro-vascular bundles and they consist of wood vessels, sieve tubes and companion cells surrounded by thick-walled fibres.

In the economy of the cane plant the stalk has three functions:

Firstly, as a mechanical structure it supports the leaves and inflorescence;

Secondly, the fibro-vascular system is charged with the duty of transporting water and food material from the roots to the leaves and carrying back to the stem the product of metabolic change formed in the leaf; and

Thirdly, the parenchymatous cells receive the material so elaborated, which is stored there or else used up as a source of energy by the growing plant.

The leaf.—The leaves of the cane are alternate and opposite, one at each joint. Leaf consists of two parts; the leaf sheath and the leaf blade. The leaf sheath springs from the node. It completely embraces, at the base, the stalk and gradually recedes from it. The sheath is colourless or pale green and about twelve inches long. The blade is from three to four feet long and two to three inches wide. The leaves taper towards the top and are delicately serrated along the margin and in many cases hairs abound at the base. The leaf has a number of longitudinal veins. The midrib is generally white, but sometimes reddish or purple and is formed with a channel-like depression in its upper surface. At

maturity leaves fall away from the stalk and in some varieties separate themselves entirely.

Function of the leaf.—It is in the leaf that the processes of metabolism mainly take place and the leaf may be considered as the manufactory of the plant. The green tissues of the leaf take up carbon dioxide from the air through the stomata, which with water transported by the roots and vascular system, forms carbohydrates, oxygen being returned to the atmosphere. At the same time nitrogenous compounds are formed through the union of carbohydrates with nitrates brought up dissolved in the soil water. The compounds so formed are transported to other parts of the plant, mainly the stalk. Another function of the leaf is the transpiration of water which takes place through the stomata.

The Flower.—The inflorescence of the sugarcane is a panicle of soft silky spikelets borne on the end of an elongated peduncle called the "arrow", arising from the terminal vegetative point of the cane. All canes do not flower and it is only exceptionally that the cane forms fertile seeds. The age at which they flower varies from 8 to 18 months and is dependent on the variety, and climate, also on the time of planting. Flowering takes place at certain definite times of the year, varying in different cane growing regions. If the cane is not sufficiently mature at the flowering time in its first year no flowers are formed until the second year. In this way a delay of a few weeks in planting will retard flowering for over twelve months.

When "arrow" appears all further growth of cane stops but the cane has not attained full maturity, ripening process continuing for a month or two thereafter.

Though flowering and setting of seed is welcomed by sugarcane breeders, as the means of providing new

varieties, it is not liked by the grower as it reduces the yield of cane. This is particularly so with varieties which when planted in some seasons, throw out "arrows" in 8 months of planting.

PROPAGATION

Sugarcane, as a crop, is grown by vegetative propagation: that is by planting cuttings known as "sets" (Fig. 1 A). Each set is a portion of the stem which consists of three eyes, except when the top set is used when it contains more eyes. In this method of growing cane, which is the only method practised in all plantations, all the plants of the variety, wherever grown, are parts of one individual cane produced originally from a seed. The great advantage conferred by this method of propagation is that the qualities of the parent plants, originally selected for commercial values, are found in all the canes thus cultivated. Slight differences among canes of the same variety, such as girth, tillerings, etc., are due to methods of cultivation and other reasons, but these differences are not transmitted, *i.e.*, are not hereditary.

Sexual propagation, *i.e.*, through seed, is solely of scientific interest and is conducted by highly trained staff at great cost by Governments. Since sugarcane is grown under divergent conditions of climate and cultivation, the raising of varieties resistant to diseases and unkind climatic variations, like night frosts, is possible of achievement only through the breeder's art. It is this aspect, the adaptation of plant to environment, in addition to raising the inherent capacity of the plant or crop-yield, that dominates the breeding work.

It is about 60 years ago discovery was made that sugarcane plant set viable seed. The deliberate breeding of cane began in Java in the year 1887 and in India

in the year 1912. The work consists mainly in collecting seeds from wind-pollinated arrows, raising seedlings from these and testing and selecting them for desirable qualities. This method is entirely empirical and success depends on chance. Emasculation and artificial fertilisation of the flower raise practical difficulties of manipulation, which makes the method unsuited for large-scale raising of seeds. Proven parents therefore go largely into cane-breeding programme. Sir T. S. Venkatraman says about inheritance in sugarcane:—

"One of the facts first noticed after the discovery of the viability of sugarcane seed was the wide range of forms resulting from the same parent, even when the needed precautions are taken against cross-pollination with other varieties. The extent of variation will be apparent from the fact that a population of over 2,000 seedlings from practically selfed flowers of striped cane of Coimbatore, did not reveal any two which were even similar when examined in some detail. In spite of this wide variation, however, there is evident a kind of family resemblance in seedlings raised from the same species or, even variety, indicating that characters are inherited in the sugarcane, though their nature is veiled and modified by other factors."

Since production of new varieties and their selection is the work of the Government Agencies, the interest of the cultivator is limited chiefly to vegetative propagation and selection of variety. Differences arising out of environmental influences are not inherited and so are not transmitted to the next generation. Heritable characters such as shape, field habits such as erect and non-lodging, vigour and yield, purity of juice and high sugar content are the real profitable qualities from the growers' point of view. Increase of yield, after the variety is chosen, should be expected therefore, by improvement in the methods of cultivation, through perfectly healthy planting material, a more rational application of fertilisers, good earthing up and proper irrigation.

CHAPTER III

PERIODICITY OF GROWTH IN SUGARCANE AND THEORY OF FORMATION OF SUGAR

A STUDY of life processes and functions of the various parts of sugarcane show that the best cultivation methods do not always give the best growth, if these are not available for the use of the plant, when they are needed most. Varying with the variety and seasonal conditions, given other conditions to be at an optimum, there are seen definite observable peak periods of growth.

In Bihar (Mushari Experimental Station) sugarcane has two periods when it grows fast: one is in early July and the other, at about the end of August or in early September. When soil moisture fell below 5% in the first foot of the soil, the growth of cane in the soils of North Bihar appeared to cease. In Mysore (Mandya Sugar Factory area), it was observed that the growing period was more uniform and the "Grand Period" of growth was from July to October, with a spurt of growth in April and May. The seasonal conditions are more equable here, with pre-monsoon showers in the months of April and May, and heavy North-East Monsoon rains in the months of August, September and October, with South-West Monsoon giving light rains with cool and heavy winds iń the months of June, July and part of August. Temperature rarely touches in the hottest part of the year, 100° F. In Central India (Sehore, Bhopal State) where temperature reaches 110° F. during May and June with dry hot winds, the growth studies, by the author, of sugarcane, during the year 1937, showed that the "Grand Period" of growth begins with the

wet-spell of the South-West Monsoon in the latter part of June and continues to the end of September. At the end of the month of October growth practically stops. Fortnightly growth studies revealed that the variety P.O.J. 2878 showed a growth of 24 inches, in the fortnight 9th July to 25th July, the biggest growth of the season. E.K. 28, though slow in growth at the beginning, had a growth of 26 inches in the same period, while H.M. 320 had a growth of only 20 inches during the same period. Such growth is not likely to be observed under more equable climatic conditions as in Mysore, where growth is more evenly distributed over a longer period, giving canes a longer period for the elaboration of juice and so resulting in a richer sugar-content.

A study of the intake of the plant-food ingredients has shown that during the young formative stage of the plant very little is taken and maximum plant-food is drawn during the "Grand Period" stage. As Nitrogen and Phosphoric acid (P_2O_5) form the most important elements required, these must be available at this stage in adequate quantity and in an assimilable form. The physical state of the soil also is very important as any deterioration in the soil condition—as want of proper drainage in clay and water-logged soils or want of adequate moisture in gravelly or sandy soils—would effect growth of cane adversely.

THEORY OF THE FORMATION OF SUGAR

The theory of the formation of sugar as the cane grows and matures is summed up as follows by Professor Went:—

" Under the influence of light, carbohydrates are formed in the leaves out of the carbonic acid and water ; probably saccharose

in the first place. This conversion is the more considerable according as more light is available. The saccharose is conveyed to the root, but when more is formed than can be removed—which, generally speaking, will happen in the day-time—the excess is deposited in the form of starch. This starch is however, also dissolved again, especially at night, and then conveyed to the stem in the form of dextrose. Also, a little levulose occurs in the eaves, which is possibly formed by a partial inversion of saccharose. In considering what happens further to sugars, we shall have to distinguish between those that are derived from older and those from younger leaves. If the sugars originate in an old leaf, they enter a full grown internode of the stem. Here saccharose suffers no further change, the small quantity of levulose combines with a part of dextrose to form saccharose ; while the remaining dextrose is gradually and almost entirely converted into cane sugar. If the sugar originates in an younger leaf, where, generally speaking, assimilation is intensive, and therefore, the quantity of carbohydrates larger, then they reach the stem top. Here the saccharose is partly inverted and that the more, as the top grows more vigorously. Because of this, the osmotic force of the cellular liquid increases, which is, in its turn, conducive to growth. Glucose is partly used for forming cellulose ; another part goes to the growing point, to combine there with nitrogenous substances to form albumen, while part of the sugars is deposited in the growing point as starch. The glucose which remains in the stem top is converted into saccharose, in proportion as the joints grow older. In the leaf sheath and young parts of the stem, sugars are often temporarily deposited along the ducts by which they are conveyed. When we consider a single internode from the moment when it is formed to the stage of maturity, we shall notice that at first, it contains no sugars but starch, as the only carbohydrate. This starch is gradually consumed, presumably for the formation of cellulose and at the same time, the internode gradually reaches a stage in which the leaf attached to it begins to assimilate. Sugars now flow-up ; the joint begins to grow, the dextrose and levulose of these sugars remain unchanged for the moment ; the saccharose is inverted for a large part. A part of the glucose goes to the younger joints at the top ; another part is used up, during the growth, for making cellulose. So at the moment the joint is full grown, it contains very little saccharose and much dextrose and levulose. Those two sugars are now

gradually converted into cane sugar, but at the same time new supplies of saccharose, dextrose, and a little levulose keep flowing up from the leaf; the saccharose is now no longer inverted, and, because levulose combines with dextrose to form saccharose, as we have seen, only saccharose and some dextrose are left at last. The quantity of saccharose therefore goes on increasing and glucose diminishes. At last the joint has reached a stage in which the leaf attached to it assimilates no longer and begins to die. Now the total quantity of sugars in the joint is only augmented by what flows in from the higher parts of the cane, in other words, what is not retained by the higher internodes. As the distance from the joint to the assimilating leaves is increased, the increase of the quantity of sugars diminishes until at last the moment has come when no sugars at all are any longer conveyed to the joint. Now there is only a decrease of the quantity of glucose, so that this, at last, amounts to no more than 0·2 per cent. of the weight of the cane; but glucose never disappears altogether. When the stage of maturity of the joint is passed saccharose is gradually inverted again. From all this we may conclude that the maximal percentage of saccharose will, for a long time, be found in that joint which is on the level of the ground or above the youngest joint that is still provided with roots; that, at each earthing up, the maximum will, therefore, be raised a little; and that, moreover, as the cane grows older, namely at the age of six to seven months, the maximal percentage of saccharose will move upwards, so that, at first, it will be a little above the ground; and finally, when the cane is ripe, it will approach pretty near to the top. This ascent towards the top may even continue, when older joints are already ripe and the percentage of saccharose is already decreasing in them."

PRIMARY FACTORS THAT INFLUENCE GROWTH IN SUGARCANE

Endeavour at the highest level is to be expected from all intelligent and ambitious cultivators in growing cane for maximum yield possible, due regard being given to the conditions under which sugarcane is grown. In theory, results of yields, as all cultivators know, depend on the integrated effect on the plant of a number of

factors. Some of these are inherent in the plant (internal), while others are influenced by environment (external). Both of them act on the plant right through the period of growth. If all these factors are present in optimum amounts during all the stages of its growth, the plant will grow to its maximum capacity which is inherent in the variety. While we think of optimum conditions, we must bear in mind that excess in some cases or deficiency of any one factor at any stage of the growth of the plant would act as a deterrent against maximum yield. Again, there is the factor of "time" or in other words, the optimum of any one factor may vary at different stages of the plant growth. It will be clearly seen, therefore, how difficult it is to produce, in practice, the theoretical maximum yield of any crop, though from calculated results of research it would be possible to arrive at the maximum yields. On such a basis, the maximum yield of sugarcane has been computed at 190 tons to the acre. Allowing a two-thirds margin for variation of factors, which are beyond the control of the cultivator, an average of about 63 tons of cane may be considered a good crop. Yields of 104 tons to the acre have been obtained in the Maharashtra area and yields of 72 tons to the acre were obtained by the author on large areas of the Mysore Sugar Factory Farms in 1934–35, varieties being Co. 419 and H.M. 320 (Figs. 17 and 18). None the less, the fact that nowhere has this theoretical yield of 190 tons to the acre has been realised shows that at some time some factor of growth was not at optimum. Successful cultivators must therefore be able to watch at each period of growth, not merely for the limiting factor but also, if possible, to rectify it. It is within the experience of every cultivator that he is helpless to do this successfully; for instance, against sunlighr, humidity,

temperature and other atmospheric conditions, while he can easily set right any deficiency or excess in soil moisture through irrigation and drainage. All this requires, therefore, in addition to means of identifying the many factors that go into the growth of cane at different stages, the power to control most of them as far as practicable. In short, the grower must live among his crop.

Dr. W. Burns in his report on "The Technological Possibilities of Agricultural Development in India", published in the year 1944 estimates the possibilities of rise in sugarcane yields per acre through improved scientific methods for different provinces as follows:—

	Tons	
North-West Frontier ..	30–35	
The Punjab	40–45	
United Provinces ..	27–35	
Bihar	25–35	
Bengal	35–40	
Madras	45–55	
Bombay, Mysore	45–55	Plant cane and
	70–80	Adsali

To reach this modest estimate of yields, in practice, against the present average of 15 tons to the acre and over 4 million acres would be an achievement worth striving for through the converging efforts of scientific, administrative, and organisational methods.

CHAPTER IV

VARIETIES OF SUGARCANE

As in other crops, sugarcane varieties come into cultivation for some time and are rejected for better varieties, especially under the conditions to suit large-scale cultivation to meet competitive demands of modern sugar factories. It would be necessary, therefore, not only to be on the watch and adopt improved varieties but to keep them pure, as mixing of varieties would harm the sugar producing capacity of the cane and entail loss.

Sir T. S. Venkatraman, speaking on distribution of sugarcane varieties in India, says (Presidential Address, 25th Indian Science Congress, 1938):—

"The sugarcanes in cultivation are devisable into two main groups, perhaps originally derived from the two wild races, *viz.*, *Saccharum Spontaneum,* and *Saccharum Robustum.* The two types show in cultivation, markedly different agricultural characteristics; the Indian indigenous canes related to *S. Spontaneum* being on the whole hardier than the thick class of canes. On account of their comparative low yields and the fact that India does not figure in sugar market of the world—not being an exporting country—the Indian canes were but little known, till recently in sugarcane literature.

Indian Canes.—Unlike most types, denoted by the type sugarcane, as ordinarily understood in the sugarcane world, the Indian canes are mostly confined to the sub-tropical areas of India. Most of them are fairly resistant to violent changes in climatic conditions and some of them to frost as well. Growing as they do, in sub-tropical India, they get but a comparatively short period of growth—perhaps six months—being limited in the early stage by severe summer and, in the later stages, by frost.

Noble or Tropical Canes.—The other group of cultivated canes is the one on which the sugar industries of the tropical world have been built. They are generally designed by the term "Noble" and, on the whole, are thicker-stemmed and broader-leafed than the first group. They generally need a longer period for full

growth, show their best performance under tropical conditions and respond satisfactorily to good treatment. The record sugar yields in this crop have been from this class of canes. They are, however, less tolerant to adverse conditions and generally more liable to disease. They are generally brighter coloured than the first group and are on the whole, softer, more juicy and possess less fibre, and as a class they have a shallower root system."

The following list gives the names of Experimental Stations in India where work on sugarcane is done:—

1. Coimbatore Central Sugarcane Breeding Station and the branch station at Karnal;
2. Jorhat (Assam);
3. Dacca (Bengal);
4. Mushari (N. Bihar);
5. Shajahanpur and Muzaffarnagar (United Provinces);
6. Jallandar and Lyallpur (Punjab);
7. Padagoan (Bombay);
8. Anakapalli and Gudiyattam (Madras); and
9. Hebbal and I.C. Farm (Mysore).

The following statement gives the distribution of improved cane varieties among the provinces:—

1. *North-West Frontier Province.*—Co. 290 occupies about 70% of the sugarcane area. Other varieties are Co. 360, 361, 312, 313 and 412. Local cane grown is Peshawar *Poundia* which is not dissimilar to Bombay *Poundia*. This thick cane is grown in rich valleys and for gur-making, which is practised as an art.
2. *The Punjab.*—Co. 285 and also Co. 213, 244, 312 and 313. The climatic conditions are the most severe for sugarcane and the indigenous types, the most primitive, are yet grown (*Katha, Dhauluand, Lalri*).

3. *The United Provinces.*—The Coimbatore canes cover about 90% of the area under cane. Co. 213 dominates the area. Other canes are Co. 290, 244, 312, 313 and 331. Local canes are *Dhaur*, *Matna* and *Kuswar* of the *Mungo* group, and *Chin* and a few others of the *Saretha* group.
4. *Bihar.*—Co. 213 is universally grown, and also Co. 210, 299, 313, 331, 421, 513, 508 and 356. Local canes are *Hemja Burli* of *Mungo* group, *Lataria* and *Bhuria* of the *Saretha* group, *Nargori* and *Samari* of the *Nargori* group and *Manaria* and *Pansahi* of the *Pansahi* group.
5. *Bengal.*—Co. 213 occupies about 80% of the total cane area, as also Co. 281, 381, 331, 421. Local canes are the thick and soft canes like *Dacca-Ganderi*, *Vendamuki*, *Shasara* and *Puri.*
6. *Bombay.*—Dharwar, Poona and the Deccan Canal area is the area of thick canes like *Poundia* and the Northern tract of Surat and Nasik is the area of medium canes like Co. 290, 213. P.O.J. 2878 and E.K. 28, both Java canes, which had replaced the local *Poundia* canes, subsequently, were replaced by the Coimbatore canes Co. 290 and 213. Now the dominating cane is Co. 419. Other varieties are 417 and H.M. 320 (Hebbal-Mysore).
7. *Madras.*—This is the area for thick canes. Mauritius canes have been grown for a long time such as Red Mauritius, Purple Mauritius, Striped Mauritius, Fiji B (Badilla of Australia), etc. The last cane is still grown for the Nellikuppam Factory and is paid a premium of Rs. 2 per ton. Coimbatore canes have

replaced all of them. These are Co. 213, 290, 281 and 243, which have established themselves in places with somewhat indifferent cultivation. The thick canes newly spreading are: H.M. 320, Co. 419, 421 and 352.

8. *Mysore.*—Local canes are *Rasthali* which corresponds to *Poundia* of Bombay, *Patta-patti, Hottecheni* and *Cheni,* the last being a medium cane and the rest thick juicy canes. Of the improved canes, H.M. 320 stood first in importance till very recently and is still the best under good cultivation for the main season. Co. 419 is rapidly replacing H.M. 320, being more vigorous in growth and less exacting in methods of cultivation. As it has a tendency to "arrow" by about October, which reduces the period of growth thus effecting the yield adversely, it is grown mainly for the late season, *i.e.*, for July and August plantings (Adsali). Other promising canes are: H.M. 661, 647, I.C. 8, 26, 74 and 131.
9. *Assam.*—Dominant varieties are Co. 290, 213, 360 and now Co. 419, 411, 421 and P.O.J. 2714.
10. *Central Provinces.*—The canes in this area include thick canes like *Poundia* and striped known as *Pachrang* and thin canes like *Khari, Kathai, Ledu.* Improved canes are: Co. 219, 210 and 237.
11. *Orissa.*—The varieties are the same as in Madras, C.P. and Bengal. The improved varieties are: Co. 213 and 285.

CHAPTER V

SOILS

SUGARCANE lives, as do the other higher plants, in two mediums, *viz.*, (i) with roots in the moist soil and (ii) with stem above ground in the surrounding atmosphere. Soils, though they appear to be static, are not so, as they are subject to continuous change due to the influence of factors like sunlight, heat, moisture, wind, chemical and biological (bacterial) actions. Of the two mediums, sugarcane gets its needs of Oxygen, Carbon-di-oxide, light and heat from the atmosphere. Man is unable to influence these factors to any great extent, to suit the growth of cane to its maximum capacity. Soil, the second medium, lends itself to be influenced to suit crop-production. It is through this medium that the various plant-foods required for sugarcane for its growth are supplied.

PROPERTIES OF SOIL

Properties of soil may be classified mainly under three heads:—

1. Chemical.
2. Physical.
3. Biological (Bacterial).

Chemical properties of soil.—Soil Chemistry, which treats of soil solutions, their reactions and their influence on plant life, has developed into a highly specialised subject and is dealt with here in general terms. Sugarcane draws its food required for its growth, other than what it takes from the air, in a state of solution through its roots. Nutritious solution of the soil may be in a state of immediate and easy availability or may be available with difficulty. Mere chemical analysis can merely

suggest what the chemical constituents of a given soil are, but it is unable to represent completely what is going on in the soil chemically in relation to the living plants and their root activities.

Colloids.—In addition to what is held in solution in the soil, there is a condition of soil, which is independent of this chemical state, known as the "Colloidal State". This again comes under another branch of Chemistry known as the "Chemistry of Colloids". Soil particles in the " colloidal state" have the "power to precipitate within themselves undissolved substances, especially inorganic plant-food, which accumulate on the boundary or outer surface of soil particles". This is expressed by the term "Adsorption". A solution passing through the soil becomes weaker in soluble substances on account of this power of "adsorption" of the soil particles. It should be sufficient for our purpose to know that "Colloids" have a very large surface in comparison with their volume, and therefore play a very important part in retaining plant-food in the soil. Some like Ammonia, Potash, Soda, Lime, Silica, and Phosphoric Acids may be adsorbed but Hydrochloric, Sulphuric and Nitric Acids may not be adsorbed.

The main functions of colloids in the soil are:—

1. They regulate the concentration of nutritious matter as an excess is injurious to plant life.
2. They "adsorb" useful matter, so that superfluous quantities of these are not washed away.
3. They retain valuable ingredients in a dissolved state, which may be directly absorbable by the roots.

Under conditions of cultivation these colloid particles, in heavy soils, may be found in fine grain structure, as under excess irrigation and in water-logged condition,

which is harmful to plant life. This state of soil condition excludes air from circulating in the soil and the physical condition of the soil becomes unworkable.

Physical properties of soil.—Soil, as we know, is made up of a large number of soil particles of different sizes expressed as its "texture". The manner they are arranged in groups or clusters is known as the "Structure" of the soil. The object of good tillage is to change the "structure" of the soil so as to encourage formation of crumb structure or soil aggregates in preference to single-grain structure. Single grain structure is seen at its maximum when the soil is "puddled" as in rice cultivation. This condition is not only not desired, but is definitely detrimental to the growth of plants. Crumb structure allows greater air penetration everywhere in the soil, keeps the soil warm, allows better penetration of roots of sugarcane and admits of better development of beneficial soil organisms.

The chief physical properties of soil that are useful to plant life are:—

1. Its capacity to hold water.
2. Its capacity to convey water through capillarity.
3. Its power to absorb heat.

The capacity of a soil to hold water is distinguishable into: (*a*) Maximum or full capacity and (*b*) Minimum, critical or absolute capacity, also known as the optimum water-content of the soil. When all the space among soil particles is filled completely with water, as during heavy rains or irrigation, it is said to hold the maximum amount of water. No air is present in the soil and this condition, continued for a long time, is detrimental to cane. The quantity of water which the soil holds when excess water flows off, as in a free soil or through efficient drains, is the absolute water-content of the soil

and it is this water we are concerned with in sugarcane cultivation. Capillary conveyance of water in soil depends on the size of soil grains or particles. Coarse sand has minimum capacity to convey water through capillarity, while very fine sand and clay have very high capillary power. Capillarity may be defined as the tendency of liquids, whose adhesion overcomes the cohesion of individual particles, to rise in narrow tubes (capillaries). Narrower the tubes, higher is the rise of the liquids.

There is, in addition to the above two kinds of water in the soil, what is known as the "hygroscopic" water, which is not useful to the plants, as it is in too close a proximity with soil grains and can be made to leave the soil particles only by applying heat.

Through good and proper tillage arable land improves in permeability, so that there is easy drainage of the maximum water of the soil, proper aeration is brought about and the soil is kept in proper warmth.

Bacterial properties of soil.—Soil is full of bacterial life. Bacteria may be classed under two main divisions:

1. Aerobic, and
2. Anaerobic.

1. Aerobic bacteria thrive in soils, where there is plentiful supply of air and oxygen. For their multiplication and growth they make use of Oxygen and liberate carbonic acid and water, of which the former is necessary for assimilation by plant life. These break up complicated compounds of vegetable matter of the soil into simple ones, which process is known as "Mineralisation", *i.e.*, conversion of complex vegetable matter into its mineral constituents such as P_2O_5, S, K_2O, CaO, MgO, Fe, Mn, etc. This process is known in common language as putrefaction. The rest is humus, a dark coloured carbonaceous compound.

2. Anaerobic bacteria, as the term implies, thrive under conditions where air or Oxygen is excluded. They use for their life nitric compounds of the soil, as the aerobic ones use carbonaceous compounds, giving off free Nitrogen. As the products of their activity they form substances which are toxic to plant life, such as nitrous acid, marsh gas, acetic acid, etc. These produce acidity in the soil, which is not desirable. These bacteria are found in marshy and water-logged soils.

Bacteria live under the surface of the soil upto about one foot deep and the soil is practically sterile at about a depth of 1½ to 2 feet.

From the agricultural point of view the aerobic nitrifying bacteria are of the greatest value and importance, as these are able to fix atmospheric Nitrogen either by themselves or in symbiosis in the nodules of the leguminous plants used largely for green manure such as sunhemp, cow-pea, etc. There are two sets of bacteria, one converting albumin into ammonia and the other this ammonia into nitrates by the process of nitrification. Nitrogen is the most needed and the costliest of plant foods in our soils and the need for growing green manure crops against this background will be easily seen.

The following extract from *Quintus* gives the several factors on which depend the effective operation of the nitrifying bacteria:—

(*a*) The presence of bases which can combine with acids such as the acid with which ammonia was originally united.

(*b*) The quantity of Oxygen in the surrounding atmosphere. It was noticed that where 11% was present, the effect was three times greater than when only 1½% was present. This accounts for the fact that the nitrifying organisms of the soil, like most other organisms, do not penetrate into clays, which proves once more the necessity for ventilating, the top layer, well.

(*c*) The moistness of the soil to which nitrifying bacteria are very sensitive. The soil must be moderately moist.

(*d*) The temparature must not be higher than 37°C. In the top stratum, therefore, there are almost no organisms in the tropics, as it is too hot and dry. It is clear therefore that the artificial manure should be buried at a fitting depth.

CHAPTER VI

MANURES AND IRRIGATION

Manures

SUBSTANCES that are supplied to the soil to correct the deficiency in plant-food and bring about increase in crop-yield are included under the term "Manure". In nature when soil is left to itself, the remains of dead plants make up the plant-food for the next generation (except in case of soil-erosion), so much so, that, as seen in forests, tendency is for soils to grow more fertile year after year than otherwise. Agriculture is said to begin where man interferes with nature and changes conditions to suit his desires. When crops are grown, removed and sold to far off places, year after year, plant-food substances are naturally taken away continuously from the soil making it poorer and poorer. Even from the physical aspect the soil deteriorates.

Of the substances indispensable to plant life and growth, Oxygen and carbonic acid are taken from the atmosphere and these are always available in required quantities. Nitric acid (Ammonia) requires to be supplied in all cases for cultivated crops, except when Leguminous crops are grown. The cheapest source of Nitrogen is through growing and ploughing in green manure crops like sunhemp, cow-pea, etc. Other sources of this ingredient are Ammonium Sulphate, Sodium and Potassium Nitrates, Nitralim or Calcium Nitrate, Cyanamide. The other manurial constituents Lime, Potash, Magnesium, Iron, etc., are required in very small quantities and are available in all soils. Phosphoric acid is not present in the soils in an available form and so has to be added.

Nitrogen Manures

These are the costliest of manures and are in greatest need in all our soils. One of the ways by which atmospheric nitrogen is fixed from the inexhaustible source of air under favourable conditions is by soil bacteria. This has been referred to while dealing with soil bacteria. The other method is through photosynthesis. Researches by Professor Dhar and collaborators, on the process of nitrification in the presence of light, show that the bacterial theory has been over-emphasised and photo-chemical nitrification in the presence of photo-sensitisers like titanium, zinc, cadmium oxides, alumina, silica, magnesia, etc., is more rapid than by bacteria alone. They proceed further to point out that addition of energy-rich compounds (carbohydrates), such as molasses, to the soil, when it is properly aerated, increases ammonia and, in time, the nitrate content of the soil.

The author from reliable and long field observations has found that an application of molasses as a preliminary to growing green manure crops has always influenced the crop in heavier yields; the bacterial root-nodules of the molasses-applied crop being bigger in size and more in number. The profitable disposal of molasses of sugar factories, except where they have distilleries, has become a problem and this method of disposal of sending it back to the soil will be found advantageous in keeping the soils rich.

A direct heavy dose of molasses to the crop of sugarcane is not recommended, as it is injurious.

Ammonium sulphate.—This is the most important, readily available, and concentrated form of nitrogen used commercially as crop-fertiliser. It is a form of synthetic nitrogen, and is a by-product in the manufacture of coal

gas and coke. It is manufactured for commercial purposes in three ways, *viz.*,

1. Arc process.
2. Cyanamide process.
3. Direct synthetic ammonia process.

Arc process.—This process involves the union of oxygen and nitrogen by means of an electric arc: a process similar to what takes place in the atmosphere through discharge of lightning in electric storms. This source is estimated to bring down every year, through rain, about 8–10 lbs. of fixed nitrogen per acre. The cost of manufacturing nitrogen by this method is very high and other cheaper methods are preferred.

Cyanamide process.—This is a cheaper method than the arc process. Raw materials used are lime and coal and the electric energy required in the process is about ¼ of that of the arc process per unit of nitrogen.

Direct synthetic ammonia process.—This is the latest and the best method of nitrogen-fixation so far developed. Quantity of Nitrogen produced by this method far exceeds that of all other processes put together, being about 90% of the total manufactured. The method is known as Haber-Bosch method. It consists in making nitrogen and hydrogen gases unite to form ammonia under certain pressure and temperature, in the presence of a catalyst.

Ammonium sulphate is a high-analysis fertiliser containing 21% nitrogen. It is free from toxic substances and its cost of transportation per unit of nitrogen is minimum (Unit is a term used to designate 1% of nitrogen in a ton of manure).

In fields where ammonium sulphate is used it is frequently seen that a white mass appears on the surface of the soil, which is mistaken for alkaline salts. It is

the result of the reaction of ammonium sulphate in the soil, which releases calcium sulphate which appears as a white mass, and is harmless.

Calcium cyanamide.—Pure calcium cyanamide contains 35% nitrogen, but the comercial brands contain 15–20% of nitrogen. It deteriorates in storage and must be applied fresh from their barrels. Calcium cyanamide should not be mixed with ammonium sulphate as ammonia will be driven off. This fertiliser is toxic to plants and is applied about ten days in advance of planting, when the soil is moist and is stirred with the soil.

Potassium and sodium nitrates.—These contain about 15% of nitrogen in soluble form and unlike ammonium sulphate leach readily through the soil and are lost to plants. These have a tendency to deflocculate clay and hence are not recommended for use in clay and heavy loamy soils.

In Nature these are found as deposits of excreta of bats in caves in Chile and other dry zones.

Organic Manures

These are generally slow acting. Their great value consists in changing the soil-complex. They release and supply secondary plant-foods also. Since a large part of the nitrogen is fixed in an organic form (humus), quantities of these must be applied in large quantities.

These manures are generally grouped under farm manure (excreta of cattle, goats, sheep etc.), dried blood, slaughter-house refuse near towns, oil-cakes, ground and steamed bone meal, etc. (*vide* Appendix for analyses).

The economic dose of nitrogen for each plantation can only be settled by experiments. Experiments conducted at Padegoan Station, Bombay, indicate that the top limit of nitrogen has not been reached at 300 lbs.,

i.e., 12½ cwts. of ammonium sulphate per acre. In Bihar (Patna) 100 lbs. of nitrogen per acre seem to be the best dose, while anything above 60 lbs. of nitrogen per acre in the heavy soils of South Bihar are found to be distinctly uneconomical. It is reported that when only farmyard manure was used to supply 140 lbs. of nitrogen per acre against the same quantity of nitrogen, through ammonium sulphate, the yield from the plot of farmyard manure was the poorest. It must be emphasised, in this connection, that farmyard manure cannot supplant ammonium sulphate for sugarcane.

Field experiments and interpretations of their results form an important portion of the study of interactions of manures and varieties. These form important basis for selection of varieties, fixing doses of fertilisers and the methods of cultivation. They require careful and complex lay out of plots according to recognised methods, such as Randomisation of plots, Latin square method, etc., and the study of results of these experiments is made through statistical method. This science has grown into a specialised branch of applied mathematics and is beyond the scope of this book. It is sufficient for the purpose of understanding the interpretations of statistical results if we know what the oft-quoted expression "Significant" connotes. It means that "the chances of results being accidental are as 20 : 1, or that the results are really due to treatment applied as 10 : 1".

Phosphate Fertilisers

Next to nitrogenous manures, in importance, come phosphatic manures. The phosphoric acid of the soil is not found adequate for full plant growth and is not in an available form.

Steamed bonemeal.—Raw bonemeal is not used

largely as it contains fatty material which delays decomposition. Steamed bone-meal consists of raw bones which are boiled and steamed at high pressure to remove fats. This process removes a small percentage of nitrogen but brings about an increase in the phosphoric acid. Steamed bonemeal contains 1–2% nitrogen and 22–30% phosphoric acid.

Dissolved bone or Bone superphosphate.—This is prepared by treating bone-meal with sulphuric acid and the product is similar to superphosphate manufactured from phosphate rock.

Basic slag or Thomas phosphate.—This is a by-product in the steel industry and ranks next in use to superphosphate. It contains 10–12% phosphoric acid.

Superphosphate.—This is a term which is generally used in reference to phosphates, the phosphorous of which is in a form readily available to plants.

Rock phosphates, which contain tricalcium phosphate and whose phosphoric acid is not soluble in water, are treated with sulphuric acid to produce superphosphate containing dicalcic and monocalcic phosphates, which are soluble in water and so available to plants. Ordinary superphosphate contains 14–25% phosphoric acid.

Double superphosphate or Concentrated superphosphate.—When phosphate rock is treated with free phosphoric acid, concentrated superphosphate containing 45–48% of almost entirely of soluble monocalcium phosphate is formed. This is preferred to ordinary superphosphate as it saves on transport.

Potash Fertilisers

These are sold in the form of potassium sulphate or chloride. Experiments have shown that this fertiliser on sugarcane has a depressing effect on the yield in

Mysore soils, as also in all Indian soils generally. They are known to improve the purity of juice of cane.

Indirect Manures

These are tank-silt, earth from old village sites, ashes, etc. These have no direct effect on the soils, but they are known to improve the general condition of the soils.

Lime has a very limited use in our soils, but is said to set free potash, soda and ammonia salts.

IRRIGATION

Seasonal needs of moisture for sugarcane vary with the age, variety of cane, climatic conditions under which it is grown, type of soil and the critical growth period. To base recommendations on monthly averages, for instance, would not be helpful. It would be unscientific. Irrigation in sufficient quantity, when transpiration, photo-synthesis and growth of cane are at their highest peak, will assuredly be of the greatest use in maximum production. 80% of the capacity of the soil to hold water is found to be the optimum for sugarcane. Irrigation experiments at Padegoan Station (Bombay) have proved that *Poundia* variety at 150 lbs. nitrogen-level (per acre) and ten-day interval of irrigation, over twelve months, 95 acre-inches gave best yield, giving increased tonnage over 70,120 and 130 acre-inches.

Methods to "stretch" water-supply when its failure is feared

Knowing the general demands of sugarcane, the problem not infrequently arises, how best to "stretch" water-supply during apprehended failure of water, *i.e.*, in summer, when the supply of water usually fails, when cane wants it most. This requires careful study and definite planning. The following measures, in this regard are recommended:—

1. Irrigate old canes, that have grown to their full, just enough to keep them alive.
2. Irrigate young canes very sparingly. This allows sufficient water to be given to canes that are in their "Grand" period of growth, *i.e.*, 5–10 months as the growth factors are functioning at their maximum.
3. Practise correct methods of irrigation, such as Long-line (Fig. 2), contour or Zig-zag (Figs. 3 and 4) on slopes, so that water is made to stand in the furrows on a dead level to be of maximum use. Do not allow water to run to waste.

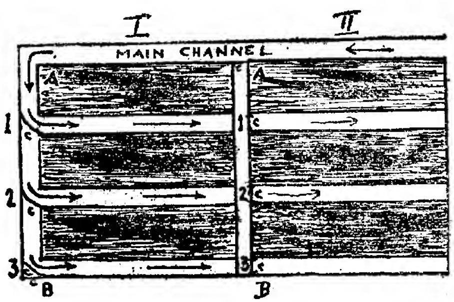

FIG. 2. Details of line-irrigation or furrow irrigation

I. Shows irrigation given from B to A. Please note the checks (C) put across the water course.

II. Shows irrigation given from A to B, with checks (C) closing against furrows.

Irrigation of plots alternately as in the sketch, *i.e.*, B to A, A to B, and so on is recommended; as it helps in controlling water best, and also facilitates inspection as one passes along the headlands.

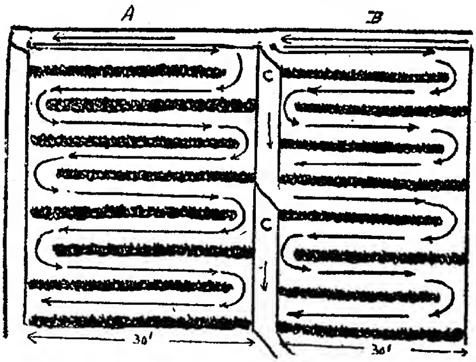

FIG. 3. Details of Zig-Zag or combination of long-line and contour method of irrigation after earthing up of cane

A. Shows wrong method. Here water, where the land is sloping, runs over double the proper distance of B. A wasteful and harmful method to be avoided.

B. Shows correct method. Checks (C) break the plot into proper units, where the irrigation water runs for 120 feet, the recommended distance; water being distributed more evenly.

4. Rush water along the furrows with a good head of water and do not allow water to flow slowly and thus allow it to go to waste.
5. Have some area under drought-resisting varieties.

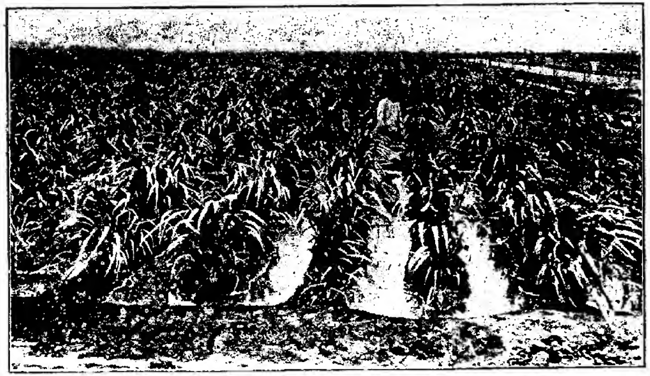

FIG. 4. Earthed up cane showing zig-zag method of irrigation.

—*Courtesy of the Agricultural Department, Mysore.*

CHAPTER VII

YIELDS OF SUGARCANE AND THEIR FIELD ESTIMATES

As already referred, there are two main factors influencing the yield of sugarcane, *viz.*,

1. The inherent (hereditary) productive capacity of the variety chosen, and
2. Circumstantial influences or external conditions that act during the growth of cane such as climate, season of planting, cultivation methods, etc.

The yields must therefore naturally vary under such conditions, even when the best possible treatment is given.

We are considering here only the yield of weight of cane per acre and not the correlation of increase in weight of cane with sugar production, or, in other words, we are not dealing with negative correlation that exists between the weight of cane and sugar per cent. This is not very important from the point of factories as we still get an increase in quantity of sugar per acre due to increase in weight of cane. Researches in Java over 25 years have shown that there has been an increase in tonnage per acre of cane, and sugar per acre therefore has increased, but sugar per cent. has remained unchanged. In India, due to introduction of improved canes, there is a difference for better in sugar per cent., but this cannot be looked upon as a progressive means of increasing sugar production, and increase in yield of cane per acre should be looked to for increasing yield of sugar per acre.

Formula for Estimating Cane Yield

The inherent productive capacity of any variety of cane, given external favourable conditions, shows itself in height to which it can grow, number of tillerings or stems it can produce per stool or clump, and girth of internodes or, in other words,

Weight of each sugarcane × the number of tillers or canes per acre
= the productive capacity of the variety, or yield in weight.

These field estimates,* worked out on this basis on factory farms and cultivators' fields by the author, have showed results within 2–3% of the actual tonnage. The following, as a working basis, is recommended:—

Average height of cane of the field, in feet × Number of canes per acre × Weight in lbs. per foot of cane
= weight of cane in lbs. per acre.

* 20–30 rows of cane per acre of representative, average growth of cane are marked by the manager in the field and number of canes got counted. From this the average number of canes in a row is got, from which the number of canes per acre is worked out. The number of canes per acre varies depending on the variety and blanks, from 26 thousand to 30 thousand. About 50 canes of average growth and size per acre may be cut, topped, stripped, bundled and weighed with a spring balance or on a portable plant-form scale. The average weight of a cane is got from this in lbs. Similarly the average height of a cane may be worked out from the cut canes and weight of cane per foot got.

CHAPTER VIII

INSECT PESTS AND DISEASES OF SUGARCANE

DISEASES of sugarcane may be caused by insects, such as borers, or by lower plant life, such as bacteria or fungi.

INSECT PESTS

The important insect pests that cause most damage to the cane are the borers. There are two kinds of borers that attack the cane. These are:—

1. *Stem-borers*, viz., *Argyria ticticraspis* and *Argyria vennosata*.—The nature of damage of this pest is the tunnelling in the tender stem in the region of the growing point which is soon seen as a "dead heart".

2. *Top-shoot borers*, viz., *Scirpophaga nivella* W. *and S. Monostigma* Z.—These attack cane after the plant is at least eight weeks old. The attack from these borers continues as long as cane goes on growing. The young caterpillars bore their way downwards through the crown into the growing point thus destroying it.

Stem-borers.—The latest method of control of the stem-borers is through biological control. The method consists in the mass multiplication of the egg-parasite of the stem-borer moth *Trichogramma minutum* R. in the parasite laboratory and releasing 6 to 8 weekly batches of them in the young crop from about the 4th week after planting onwards. This method is successfully practised over about 10,000 acres of the factory area in Mandya.

A study of the incidence of the stem-borer shows that the attack is heaviest in summer months and the

cane planted after the month of February suffers badly. Early planting is indicated.

Top-shoot borer.—The control of this pest consists in systematic removal of moths and egg-masses from the fields upto about 3-4 months of planting.

The following steps are recommended against the attack of borers:—

1. Plant borer-free cane-sets.
2. Cut out all "dead-hearts" as they appear in the field. Merely pulling the "dead-hearts" will not kill the borers. The knife should be used right down into the stem.
3. Collect, rigorously, moths for about three months after planting, from small trash heaps stooked in plots, at the rate of about 4 to 6 per acre. This can be done cheaply by boys and girls going round in the mornings, shaking them, collecting and killing the moths. Let the fieldman check every afternoon and destroy the moths.
4. Egg-masses that can be seen easily on the back of the leaves should likewise be collected and destroyed.
5. Light earthing of cane to cover the bottom of the stems of young shoots helps in controlling the pest.
6. In harvesting old cane it is important that the cutting should be done below the ground, thus practically eliminating all borer stages from the stubble.
7. Burn all trash, etc., in nearby fields after harvest of cane as thoroughly as possible to destroy

all borer larvæ hidden or hybernating in the trash. This will reduce the borer-survival considerably.

8. General clean up should be rigorously practised in all cane plantations.

Other important insect pests that attack sugarcane from outside are white-ants and Pyrella.

Attack of white-ants can be controlled through copious irrigation and application of crude oil in irrigation water at the rate of 5 seers per acre. Application of *Honge* (*Pongamia glabra*) or Neem (*Melia azadirachta*) cakes at the rate of about 20 maunds per acre about a week before planting is found to reduce the attack of white-ants. Dipping sets, before planting, in lime-water and painting cut-ends with coaltar are also found useful.

Pyrella is found to do considerable damage to cane in Central and Northern India and in the East Madras Coast. It is not known in Mysore as a pest. The hoppers by sucking the plant-sap weaken the plant at the critical stage of growth. "Bagging" of adults and nymphs by field nets, collection of egg-masses and stripping of leaves of cane are recommended.

Bacterial and Fungus Diseases of Cane

These diseases are not much in evidence among the improved varieties of cane and under good cultivation. The most important of the diseases are:—

Red-rot.—This usually appears in ill-drained plots. It is due to a fungus. Its characteristic is that light-coloured spots appear in horizontal direction through the internode surrounded by a bright red discolouration, increasing in intensity towards the edge and ceasing abruptly. An acid smell also is noticeable. A strict

selection of sets from disease-free source and good cultivation are recommended. Growing of disease resistant varieties is a necessary step.

Other diseases like pine-apple disease, sereh, gumming disease, chloratic-streak and black-rot may be mentioned. Dipping sets in one per cent. solution of Bordeaux mixture as a preventive is recommended. For *virus* attacks like *sereh* and *chloratic-streak* diseases steeping the sets for twenty minutes in hot water at 52° C. is recommended.

PART II

PRACTICAL SUGGESTIONS FOR SUGARCANE PLANTATIONS

The future of the Sugar Industry depends mainly on the cost of producing the primary material, *viz.*, cane, and the problem is, therefore, one of protecting a particular branch of agriculture until such time as improvements in methods of cultivation and development in research enable the agriculturist to increase his yields per acre, and thereby effect a substantial decrease in the cost of cane, while maintaining or increasing his own profits.

—*Tariff Board Report*, 1931.

CHAPTER I

CLIMATE AND SOILS

MYSORE ENJOYS MILD AND EQUABLE CLIMATE

THE Mysore State is a tableland having an area of 29,458 square miles situated in the angle where the Eastern and the Western Ghat ranges converge into the Nilgiris. It enjoys a very mild and equable climate. The highest temperature in shade hardly touches 100° F. in Bangalore and in Chitaldrug, the driest district, it hardly touches 102° F. The lowest temperature reached is 48° F. in Bangalore and 42° F. in Hassan.

The seasonal rainfall generally begins with pre-monsoon showers known as "Mango-showers" from about the last week of March to May, which gives a precipitation of 2–4 inches. This corresponds to the first short "grand-period" of growth of sugarcane. The reason for earthing cane by now will be easy to understand against this background. About the 10th of the month of June, the South-West Monsoon commences with its high winds and lowering of temperature. This covers the period of the months of June, July and August. This period gives a precipitation of 10–12 inches in parts of Maidan and about 60–100 inches in Malnad. At the break of the North-East Monsoon the wind stops, humidity goes up and we get a precipitation of 15–25 inches in the latter part of August and in the months of September and October and upto the middle of November. These rains are very important to all Maidan crops and sugarcane puts in the maximum growth during this period. With the end of this monsoon the weather turns dry and cold, the growth of sugarcane stops, and the arrowing types of cane will have thrown out arrows.

The cane now begins rapidly to mature. The main working season for the sugar factories begins.

Season for Planting Sugarcane

The main season for planting cane is from the end of November to end of February. The canes planted during this period escape the attack of borers and have a long season of growth. As hot weather advances, the attack of borers increases. With regard to most of the improved canes, which arrow in the month of September to October, late planting definitely reduces the period of growth, thus resulting in lower yields. The second season for planting is in the months of July and August and this cane can be left to grow, where the land can be occupied by this crop for more than the normal period of about 12 months, for about 14–16 months.

The area from which the Sugar Factory at Mandya draws its cane is within a radius of 10–15 miles from the factory. The factory is situated on the metre-gauge railway between Bangalore and Mysore, about 60 miles from Bangalore and 30 miles from Mysore. The area is commanded for irrigation by one of the largest irrigation schemes in the world—Krishnaraja Sagar which irrigates 1,20,000 acres. The climate, as explained above, gives the cane conditions for a long period of growth, allowing formation of more sugar than in North India. When this factory used canes grown on the factory farms under strict scientific control for second half of its working season during the first year of its working, the percentage of recovery of sugar was 11·75, practically highest for India. The factory has a capacity of 1,400 tons and can work about 290 days in the year against 100–120 days in Northern India. These advantages are due, as one can see, not a little, to the climate.

The following statement gives the area under sugar-cane in Mysore State for the years 1941–42 and 1942–43:

District		Area under Sugarcane		
		1941–42	1942–43	
Bangalore	..	4,700	4,502	
Kolar	..	7,845	7,392	
Tumkur	..	2,791	2,204	
Mysore	..	1,931	1,811	
Mandya	..	13,668	11,511	Factory Area
Hassan	..	5,651	5,258	
Shimoga	..	6,018	6,333	
Kadur	..	2,169	2,204	
Chitaldrug	..	1,512	1,256	

Soils and Their Classification

Soils may be classified roughly into:—

1. *Gravelly or Stony.*—These soils will be found usually under new irrigation schemes. Not being under intensive cultivation under the previous dry-crop farming and due to geological formation, these lands are generally coarse, shallow and poor.
2. *Red-Loams.*—These soils are deep, free and easy to work. They respond well to good treatment.
3. *Clay Soils.*—These soils generally are rich, being under good cultivation for a long time. They are found under all old irrigation schemes.

The three kinds of soil mentioned above may be classed also as:—(1) Coarse, (2) Medium and (3) Fine.

Fertility of a given soil depends on its mechanical, chemical and biological properties. We have already mentioned in Part I that the chemical and biological properties of a soil depend mostly on the physical condition of the soil, *i.e.*, "Structure", which may change rapidly under cultural treatment, while "Texture", which

depends on the original rock properties from which it is derived, changes very slowly.

Mapping out Soil Types

The short description of classification of soils is given in popular terms to emphasise the need to map out types of soils in sugarcane plantations, so as to enable the Manager to distinguish easily the different types he has to deal with. This would enable him not only to select cane varieties to suit peculiarities of soil conditions, but also to decide the methods of cultivation in regard to systems of irrigation, manurial doses, drainage, etc.

Surveying and Levelling

This step, which must include surveying of fields or plots and running of levels for laying out plots on the contour, wherever necessary, will fix the plots with regard to area and peculiar systems of irrigation, as contour or otherwise, permanently, so that this work is saved from being gone over every year. Coupled with this, the cropping scheme should be worked out well in advance to suit conditions of each plot including labour and other factors, so as to converge all efforts at getting highest yields at the greatest profit based on highest field and labour economy.

CHAPTER II

GROWING GREEN-MANURE CROP PREPARATORY TO SUGARCANE

THE need for growing a green-manure crop, previous to the sugarcane, is greatest in our soils which lack "humus". We have already referred how these crops fix atmospheric nitrogen and the nitrogen thus fixed gives the cheapest source of the costliest plant-food. In addition, the crop, adding humus to the soil, brings about favourable soil changes by improving its physical properties.

USE OF MOLASSES AND ITS APPLICATION

Wherever molasses is available, it should be most advantageously applied to the soil in irrigation water at the rate of 8–10 tons per acre. Molasses for this purpose should be stored in the plots at convenient distances near water courses in pits, and may be emptied into the irrigation water in measured quantities by buckets to supply the desired dose. The land should be lightly ploughed or disced as often as possible. About a fortnight later a light log of wood should be passed over the plot to slightly pack the soil and the plot irrigated heavily. When fit, green manure seed (san-hemp and cow-pea) at the rate of about 50 seers per acre is broadcast, disced to cover the seed and a light brush-harrow passed to give a firm seed-bed. The author cautions against reversing the process, *i.e.*, irrigating the plot after sowing the seed for the very simple reason that it produces the bad effect of a heavy rain after sowing. The injurious effect of a heavy rain after sowing is too well known to good cultivators. Two or three irrigations at an interval of 10–12 days, depending on soil and weather conditions, may be required

to bring the crop to the stage for being ploughed in. On no account should the crop be allowed to run to seed; the best time for ploughing in the crop is when the crop begins to flower. This gives the best results with regard to providing the soil with rapidly rotting material with its maximum amount of nitrogen. A good crop of green manure of about 10,000 lbs. is estimated to give 150–200 lbs. of nitrogen per acre in the organic form.

With a heavy stand of green-manure crop, there arises the problem of incorporating it into the soil. The author has used successfully for this purpose a bent rail piece tied with an iron chain or rope to the beam of the

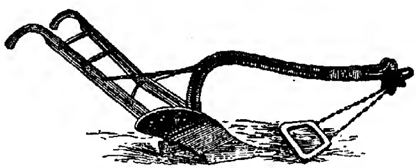

FIG. 5. Plough with bent rail-piece used for ploughing in, a standing crop of sannhemp, in one operation.

plough which, as the plough is drawn, pushes down the crop to be turned over by the plough in one operation (Fig. 5). A log passed over the ploughed land will accelerate conditions for rapid decomposition.

CHAPTER III

PRELIMINARY OR PREPARATORY OPERATION

A WEEK or ten days after the green-manure crop has been worked into the soil, the main ploughing for preparing the land for the cane crop should begin. This must be done thoroughly and with the plough set for as deep as it can go. Where tractor ploughs are used, they may be set to go as deep as 12–15 inches, if soils allow.

"SPLITTING" AND "GATHERING"

Care must be taken that in ploughing with mould-board ploughs the plots should, in alternate years, be "Split " and "Gathered" (*vide* Fig. 6). It is a common phenomenon in continually "Split" plots, as is found in local practice (in Mysore), because of the bullocks being trained to turn at the headland to their left every time that, after a few years, the edges of the plots not only become higher in level which interferes with proper irrigation of the plots, but also grasses and other weeds near the boundaries spread into the plots. To overcome this defect the author recommends that the last strip be "Gathered" in the final ploughing, which helps in keeping the boundaries of plots cut clean and clear of weeds.

OPENING FURROWS

When the land is fit, a log (heavy or light depending on whether there are clods or not) is passed across the ploughed land which, while evening out the surface, makes it easy for the operation of opening furrows at 3 feet apart, the standard distance found best. A heavy double-mould-board plough or ridger, like Kirloskar's or

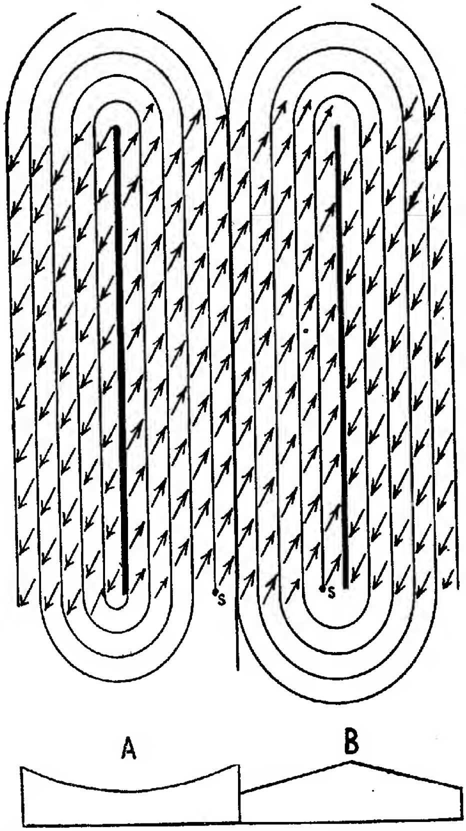

FIG. 6. Two methods of ploughing with mould board ploughs

FIG. 7. Opening furrows three feet apart with a heavy ridge plough (Bullock power).

Note how the bullocks walk in the furrow previously opened without disturbing the ridge.

A. "Splitting." (S) shows starting point of ploughing. Arrows indicate the direction of the turning of the furrow.

Centre line is the drainage furrow.

B. "Gathering." (S) shows the starting point of ploughing. Arrows indicate the direction of the furrows. The centre line is a ridge thrown up by slices one against the other at the beginning of ploughing. Sections show how plots get uneven if only one method of ploughing is adopted, year after year.

Cooper's, is used for opening the furrows, set for the greatest depth the soil permits. A special yoke to keep bullocks 6 feet apart or 3 feet from centre of the yoke, will make bullocks on one side walk in the furrow while opening the next one without disturbing the already opened furrow (Fig. 7). This is continued till all the furrows in the plot are opened. Where the need is for opening furrows on the contour in a slopy land, the furrows follow the contour and are not straight, if contours take a curve. It should be seen, however, that furrows are opened across the slope and not down the slope, or parallel with the incline, to prevent washing out of manure and setting up soil erosion so as to allow irrigation water to stand in the furrows on a dead level to be of maximum use to the plants.

Drains

Main or Round Drain, if there is none, should be dug round the plot. It should have the following dimensions:—

$2\frac{1}{2}$–3 feet across at top
$1\frac{1}{2}$ feet across at bottom
$2\frac{1}{2}$–3 feet deep.

This may be done in two stages, if necessary, depending on labour conditions, but the drains must be ready before the heavy rains begin.

The general or basic dose of manure is applied now to the furrows and mixed with the soil (*vide* under Manuring for details).

Plots to be Divided into Strips

The plot is now divided into convenient strips by opening water courses to lead water to the furrows from the main water channel. These run down the slope and across the furrows which run across the slope. These water-courses, depending on the lay of the land, may be 25–35 feet apart or even 100 feet in case of level plots. They should be made watertight as far as possible. It is done by two women, facing each other, going along

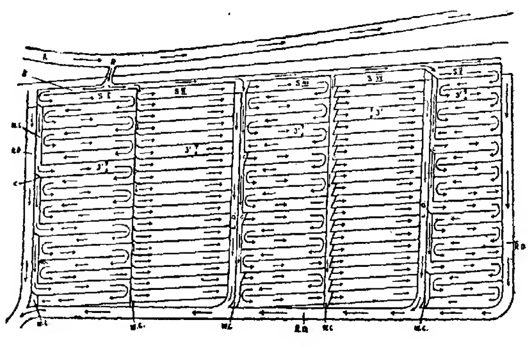

Fig. 8. Plan of general lay-out of sugarcane plot

A. Main irrigation channel
R. Regulator to control water entry into the plot
B. Water course for the plot
R. D. Round or Main drain to drain the plot
Top width—2½ to 3 feet
Bottom width—1½ foot
Depth—3 feet
L. D. Lateral drains:
Top width—2 feet
Bottom width—1 foot
Depth—2 feet

Note the curved joints where the laterals and the Mains meet, to prevent silting up.

W. C. Water course inside the sugarcane plot for line or furrow irrigation, and zig-zag irrigation.

S. I, II, III, etc., are strips of plots of 30 to 50 feet broad according to convenience for handling, depending on slope of the land.

Irrigation systems in S. I, III, and V show zig-zag or combination of long-line contour. This method is followed from the final earthing of cane to end of harvest. Irrigation in plots S. II and IV show line or furrow method. This is the method of irrigation adopted from planting of cane to earthing up.

Note the checks (C) to impound irrigation water in the furrows. In the zig-zag system the length of the run for water is broken by these checks into the recommended distance not to exceed 120 to 150 feet.

Arrows show direction of flow of water.

the water-course smearing thickly the insides with slush from the water-course.

In case the plots require additional drains (laterals) later, the space allowed for the water-courses must be wider, *i.e.*, 2½ feet (2 feet for drain and ½ a foot for water-course) (Fig. 8).

CHAPTER IV

PLANTING OF SUGARCANE

Sets for Planting—Kinds and Their Preparation

Propagation of sugarcane, as has already been pointed out, is done vegetatively, as sexual propagation is unsuited because of the wide variability of the progeny.

In practice and in all cane growing countries, it is customary to use for purposes of sets the top portions of full grown canes ready for crushing from one's own cane crop or from neighbouring plantations. While this would, no doubt, mean economy, as top portions of cane contain less sugar than middle and bottom portions and, in addition, saves labour and cost of growing nurseries for the purpose, it should be pointed out that the improved varieties of cane have a tendency to arrow and, as they ripen, the eyes in the top portions begin to bulge out and sprout, which detracts from their value as planting material. Sets from such a source, not sprouting satisfactorily, cause a number of blanks. Nevertheless, the cheapness of the material is a point in favour of this source.

Special Nursery for Sets

The other and decidedly more satisfactory source of planting material is from nurseries raised specially for the purpose of providing sets. The canes thus grown give the best planting material and have about 8–10 months of growth at the time of harvest. The distance between the rows of plants in the nurseries may be 2 feet and sets planted end to end in the row. One acre of such nursery with good cultivation and adequate manuring will be able to supply sets for 30–40 acres.

C. N. Agarwala in the *International Sugar Journal*, May 1944, says on the subject:—

"Normal interplant distance is 3 feet. Reduce it to one foot and ⅓ acre will carry as many sets as one acre. Each set gives, with four tillers in eight months with adequate fertilisers, 20 sets and one acre of nursery thus can plant 60 acres."

In a well-planned plantation, nurseries (raised 8–10 months before the main season for planting) in selected plots near main areas of planting, contribute greatly to an assured supply of the best planting material.

Short Crop

When these nurseries are harvested for sets, the stools may be allowed to grow again (short-cropped). The stubbles are cut back deep under the soil surface and the sprouts that appear are treated in the same way as plant-cane and harvested at maturity for milling. These crops will give as heavy a crop as plant cane. A second cut or ratoon may be taken with careful tending.

Preparation and Selection of Sets

Sets consist of cane cut into lengths with a sharp bill-hook or cane knife and contain 3 eyes or buds each (Figs. 1 *a* and 9). These may be:—

1. Tops from ripe canes cut for milling.
2. Cut-up whole canes from nursery or from ripe canes.

Portions of healthy canes 2–3 feet from the top give satisfactory material for making sets.

A strict selection of sets is emphasised, rigidly discarding those showing the slightest signs of any disease such as red-rot, signs of borer-attack, etc. It is through bad sets that diseases are carried into the plantations,

blanks occur due to faulty sprouting of sets, "laggards" which reduce cane-yield appear, and loss of sugar in cane occurs. Bad sets, carried to the plots and planted, cost the same as good sets in labour and material but produce no results at harvest.

Top-sets are cut from tops of canes which are quite healthy in appearance of good sprouting ability and about 1–1½ feet long. Adherent leaf-sheathes are stripped to facilitate easy development of roots from the root zone of the node which, otherwise, have to pierce through the hard enveloping leaf-sheathes.

The stripping of leaves from cane required for sets is done by hand carefully, so as not to damage the eyes. The cane is cut at a slant, top downwards against a piece of wood with a sharp cane-knife (Fig. 9), each set to consist of 3 eyes. In case of cane having 7 eyes left at the end, sets may be of 4 and 3 eyes each. If cane happens to be one of long internodes and a set of 4 eyes happens to be very long, sets may be prepared with 2 eyes.

It is best to keep separate the top-sets and sets of cut-up cane and plant them separately. The methods of planting of these sets differ. Top-sets are planted with a slant with tops showing above ground burying only the lower 2 or 3 eyes. Cut-up sets are buried completely in the soil. Top-sets sprout quicker than cut-up cane sets. Sets of different varieties of sugarcane should likewise be separately grouped for planting separately.

Pre-treatment of sets is not usually done, as a rigorous selection assures good material for planting. Soaking sets in running water for 24–48 hours, in the author's long experience, helps quicker and better sprouting. This is recommended for all cut-up canes and is recommended as a measure against any borers and other insects that might be harbouring in the set. An easy method for

FIG. 9. Cutting sugarcane sets for planting. The women are selecting good sets, rejecting borer-attacked and diseased ones.

FIG. 10. Sets spread on top of the ridges, ready for planting. Water course, running across the furrows, is seen in the fore-ground.

Bhopal State Sugar Factory is seen in the background.

FIG. 11. Planting sets.

The woman on the right shows position of set as she pushes the set gently into the mud, while the woman on the left shows the final position of the planted set as she withdraws her hands from the soil.

steeping sets in water is by closing the lower ends of drains temporarily, filling them with water and putting sets in them to soak. Soaking sets in lime water gives better results and may be done where facilities exist and with valuable seed-sets.

Spreading Sets for Planting

Before the sets are spread it must be seen that the plot is perfectly clean and free from weeds, any weed that might have appeared being removed.

The selected sets, as many as required, are carried in baskets and are distributed carefully on the ridges by women or boys (Fig. 10). They walk in the bottom of the furrows without disturbing the ridges. Further selection of sets at the time of distribution is recommended to see that sets with damaged eyes are not planted. To provide for the extra seedlings required to fill in blanks at a later stage, it is better to plant double rows of sets every 30 or 40 rows. The author prefers to have for this purpose a raised nursery planted at the same time in a corner of each plot. The sets in the nursery must be placed one slanting against the other and covered with a mixture of sand and farm-manure and water sprinkled to help sprouting. These can be removed with greater ease when required and carried in baskets with care for planting in the fields to fill in blanks. With selection of sets rigorously done, 8–10 thousand sets should be sufficient for planting an acre.

Planting

Irrigation of strips is now undertaken with sufficient head of water in the main channel so that furrows may be quickly filled. Perfect control of water must be insisted on, to see that water keeps to the furrows and does not spread all over the plot. Women follow in the

wet furrows, take the sets spread on the ridges and push them (not press them down) into the soft wet earth, not in the centre-bottom of the furrow where the ground is hard and may harm the eyes, but at the bottom towards and near the ridge away from the centre of the furrow, where the soil is soft (Fig. 11). This method keeps the bottom of the furrows free for work-men to walk without damaging the cane plants during subsequent manuring, weeding and other operations. In planting sets, it should be seen that the eyes of the set are at the sides, and not downward or upward, to give equal chances for all the eyes to push their young shoots through soft soil, which will not be the case if some eyes face downward.

WATERING

Watering must be done regularly and as often as necessary, depending on the nature of the soil, so as to keep the soil moist to facilitate even sprouting. In gravelly soils, irrigation will be necessary at intervals of 4–5 days and in heavy clay soils irrigation should be at longer intervals—may be a week or ten days or even more. Irrigation must be done under strict control, as otherwise it encourages growth of weeds and brings about undesirable soil conditions by spoiling the desired crumb structure. As plants grow, for an intelligent cultivator, the plants themselves will indicate whether they require water or not. It is impossible to lay down accurately when a crop requires water, but it must be borne in mind that the optimum water requirement for sugarcane is 80% of the water-holding capacity of the soil or roughly, the soil should always be kept moist.

WEEDING

In about 15 days after planting shoots of sugarcane will be seen in rows. Three weeks after planting, the

first weeding should be given. This requires careful watching as the plants are small and tender and damage may be caused to young plants. This is the time—at any rate not more than a month from the time of planting—when filling of gaps must be undertaken. With the best of care and attention, in selection of sets, gaps will be found and some plants will also show a lack of vigour (laggards). These are the weak spots that give rise to patchy portions in plantations. Now is the chance to correct any planting mistakes and the farm manager should be impressed about the urgency and importance of this operation.

Filling Gaps

This should be done with extreme care and the following method has been found successful and may be followed:—

The author prefers, as already noted, to have raised nurseries for each plot, but in case this has not been done, utmost care should be exercised in removing extra plants from the double-rows from fields. On no account should they be pulled out or picked, as it injures or snaps the roots and is harmful to the young plant, as the plant has to develop fresh roots to begin growth. These young plants should be carefully removed after irrigation, with the earth round them pressed into a ball, and placed in baskets. The leaves of these supply-plants should be clipped short to reduce evaporation. The gaps in the fields should be marked well in advance and the men should dig holes large and deep enough to receive these plants with the ball of earth round them. Compost or well rotted Farm manure and an extra dose of ammonium sulphate is thrown into the pit. The plant is carefully lowered .into the pit and earth pressed all round it

to give a firm hold and then watered. Extra watering—hand watering if necessary—is given until the plants take root.

In case of nursery plants, their removal is much easier and they may be carried few at a time in baskets for planting. All the care in planting and watering as described above is, of course, necessary.

FIG. 12. Spreading ammonium sulphate round young plants of cane. This method easily washes out the fertiliser, and, further, is above the root-zone. (A wrong and wasteful method.)

CHAPTER V

AFTER-CULTIVATION

AMMONIUM SULPHATE DRESSING

AFTER the operations of weeding and filling gaps, is the time when application of ammonium sulphate is to be taken up. This is about 5–6 weeks after planting. Spreading the fertiliser on the surface, in furrows, should never be done (Fig. 12). It is wasteful as the irrigation water may carry it away and, moreover, the ammonium sulphate thus given is above and beyond the roots-operating soil portions of the root zone. Java method is the best. This consists in making holes with pointed sticks (iron-tipped for durability) (Fig. 13 *a, b, c*)

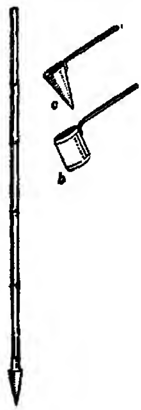

FIG. 13. (*a*) An iron-shod bamboo used to make holes between stools of sugarcane to receive measured quantity of ammonium sulphate.

(*b*) and (*c*) Two tin measures with handles used in applying fertiliser in holes.

between stools, about 4 inches deep, into which measured quantity of ammonium sulphate is dropped (Fig. 14). These holes must be just above the water line and not at the bottom of furrows where water flows. The method is found to give maximum results as the fertiliser is down below and in the root zone and the moist soil makes it available as required by the growing plants (see inset Fig. 14). The quantity of fertiliser

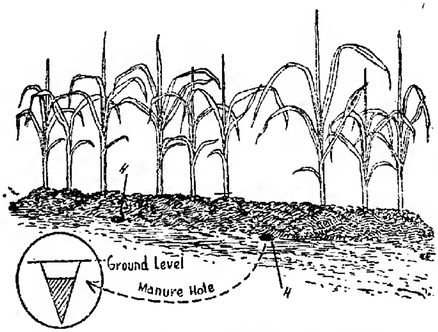

FIG. 14. Shows position of holes (H) for applying ammonium sulphate in an young crop of cane.

Inset shows the section of the hole with ammonium sulphate : (shaded portion).

to be given is previously fixed for each field and variety. The way in which ammonium sulphate acts in the manure hole is described by Quintus thus:—

"After a watering the sulphate is dissolved and will be absorbed in a thin layer around the sides of the hole, but at a depth where drying out will be gradual. Nitrification will therefore go on unhampered, and the Nitrate formed will gradually diffuse in all directions and in this manner will, everywhere, get within reach of roots. When the roots absorb it, more Nitrate

will spread in that direction to restore the equilibrium. It is clear from this, that deep manure holes are very desirable. Generally speaking, manure holes cause the manure to be sooner available in deep layers, stimulating the plant to form a deep root system, which is found to be very desirable." (See insert Fig. 14.)

When the crop is 2½–3 months old and before earthing, the final dose of ammonium sulphate should be given so that all the required amount is buried deep in the root area.

Manuring and Irrigation

Manuring.—Before planting sets, as a general basic acre-dose, a minimum of 10 cart-loads or 5 tons of Farm-yard manure or compost, one hundred-weight of concentrated superphosphate or 2 cwts. of ordinary superphosphate and 2 cwts. of ammonium sulphate should be given in furrows and lightly mixed with the soil. Six weeks later 2 cwts. of ammonium sulphate is given in holes by the Java method. When the crop is about three months old, the final dose of ammonium sulphate of 3 or 4 cwts. per acre is given by the Java method. It should be seen that the plots are kept absolutely free from weeds before applying the fertiliser.

As there is world shortage of supply of ammonium sulphate, which may continue for some time, a substitute manurial formula is given to be used till proper supplies of ammonium sulphate become available:—

1. A minimum of 10 cart-loads or 5 tons of compost or Farm-yard manure and 2 cwts. of steamed bone-meal at planting.
2. 3 cwts. of ammonium sulphate six weeks after planting, in holes (Java method).
3. ¾–1 ton of powdered groundnut cake in furrows before the final earthing up, *i.e.*, about 3 months after planting.

Irrigation.—While dealing, in Part I, with principles of growing cane, we have dealt with the part irrigation plays under varying conditions of soil and plant growth. The cane is planted in furrows, in rows 3 feet apart, which is found to be the most economical and best method. To suit this, line irrigation (Fig. 2) is done until the cane is earthed up, *i.e.*, to about three months after planting. During this period water is allowed at required intervals to flow into the furrows until the water reaches about three-fourths or more of the length of the furrow when water is cut off, while the flow of water covers the rest of the furrow. A good head of water should be assured to enable rapid work. This should be particularly attended to, as, otherwise, the turn out in the day's work becomes less and costlier.

After the crop is earthed up finally, furrows are turned into ridges and ridges into furrows and the method of irrigation will vary between zig-zag system (Figs. 3 and 4) and Long-line contour depending on, whether the plot is on a level or on a slope. A combination of both may be found necessary in some places. These systems assure proper water supply, as water stands on a level between rows of cane thus giving the best results.

EARTHING

In about a month and a half to two months from the time of planting, light earthing is done. This is done generally by having a plough passed carefully in the furrow to throw up the earth to cover the bottom of the young plants. It is recommended also as a measure to check the attack of stem-borer. This method, with the best of care, disturbs the water courses and interfers with proper irrigation, unless water courses are set right

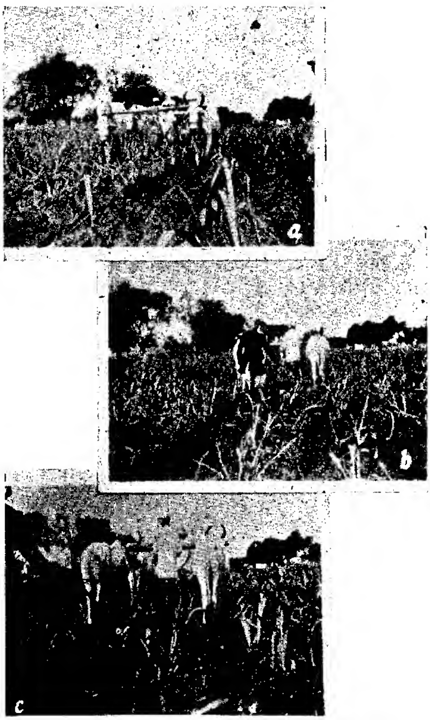

FIG. 15. (*a*) Heavy ridge-plough being worked between rows of young cane (Front view).

(*b*) Same as *a* but back view.

(*c*) Same as *b* close view.

In all cases, note how bullocks are made to keep between the rows of young cane without damaging them.

again. The author prefers earth from the ridges, which is friable and in good form, to be made use of to cover the bottoms of young plants, leaving the water courses and furrows clear. This can be done by cheap boy-labour.

It is difficult to fix exactly the number of earthings required and when each one is to be undertaken, as it depends on the growth of cane. Some varieties such as Co. 419, H.M. 661 on account of their vigorous and rapid growth require earthing sooner than the slower H.M. 320. The final earthing is generally done in about three months' time and in any case should not be delayed beyond four months.

The final earthing is done as follows:—

After the last dose of ammonium sulphate is given (in holes) or one ton of groundnut-cake is given in furrows, the plot is copiously irrigated to soak it thoroughly. When fit, mould board ploughs such as Kolar-Mission, Mysore or Verity is used carefully to plough the land between the rows of cane, without disturbing the plants. This is easy to do by making use of the yokes used for opening furrows, as they will keep the bullocks between the rows of plants. Bladed-harrow (*Dodkunte* or *Bakhar*) with 2 ft. 4 inches blade is passed which gives the soil the necessary working condition. A heavy ridge-plough, the one used for opening furrows, is now used to earth up the cane. (Fig. 15 *a*, *b*, *c*). The final finishing, which includes laying out water channels for irrigation according to the system decided upon, is done by human labour. It should be seen that as much earth as possible closes round the stems firmly without leaving any hollows between the stems and the tops of ridges, where rain water may collect and harm the cane (Fig. 16). Rigorous supervision is called for to see this operation

satisfactorily done, as it is the last and one of the most important operations on which the growth of cane depends.

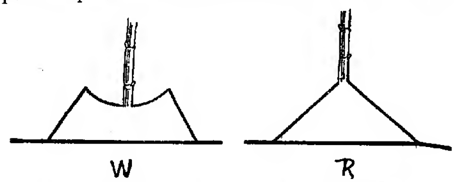

FIG. 16. Final finishing of earthing of sugarcane

W shows wrong method of finishing, leaving space between cane and the earth round it.

R shows the correct method of finishing. Note how the earth firmly closes round the plant.

The plot is now finally laid out with irrigation and drainage channels within the plot to suit the system of irrigation and drainage decided upon. The lateral drains, to drain the inside of the plots, run at right angle to the main drain that encircles the plot, emptying themselves into it. These subsidiary drains take the line of water courses down the slope, for which provision should have been made during the time of planting at distances as required by the drainage needs of the plots (see Fig. 8 General lay-out).

Good irrigation from now onwards is easy and is attended to as a routine operation at proper intervals. It should be borne in mind that as growth of cane increases, irrigation should become more plentiful and any shortage of water supply will affect the growth of cane adversely. Generally, irrigation at ten-day intervals should be sufficient, but the appearance of plants should be the guide. If the leaves show curling of tips pointing upwards, it is a sign that the plants are not having adequate supply of water. The same signs may appear

Fig. 17. Sugarcane crop. H.M. 320 and Co. 419. Note the arrowing in Co. 419.

(Courtesy of the Mysore Agricultural Department.)

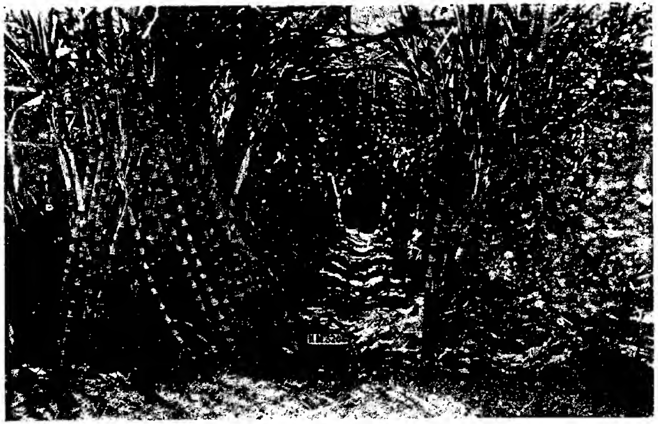

FIG. 18. H.M. 320 crop. A close view.

(Courtesy of the Mysore Agricultural Department.)

even with adequate water supply, when plants strike against a rocky sub-surface.

Removal of Late Tillerings

Such of the tillerings that appear after five months from planting should be strictly removed. These will not come to maturity along with others and not being ripe at the time of harvest will lower the purity of juice. Nevertheless, they draw upon the plant-food of the soil which should better be used by the older canes.

Drains—Their Care

Drains, to recapitulate what has already been noted in Part I, play a very important role in helping soil-aeration, removing the injurious excess or free water from the soil, increasing favourable conditions for deeper penetration of roots and, in general, improving the physical condition of soil by permitting "Crumb-Structure" which is an essential condition of a good soil.

The following are the dimensions of different kinds of drains:—

Main Drain round the Plot—

$2\frac{1}{2}$–3 feet across at top.
$1\frac{1}{2}$ feet across at bottom.
3 feet deep.

Lateral or Subsidiary Drains—

$1\frac{1}{2}$–2 feet across at top.
1 foot across at bottom.
2 feet deep.

A plan of irrigation and drainage in a plot is given in Fig. 8.

The drains must be ready to function before the heavy rains set in, usually before July. It is necessary

that these drains must be kept clear of obstructions and are maintained at proper depth to get the best results.

As cane grows and the time of maturity approaches, the lateral drains may function only partially due to fallen leaves etc. It will be found sufficient if the main drain round the plot is kept in good repair.

Wrapping and Propping of Cane

This consists in wrapping canes with their own leaves, from below upwards to protect them from damage from rats etc., and from lodging. The canes are tied up, supporting each other, to prevent their falling. This is done to soft varieties of thick canes. It is not attempted on a plantation scale with improved canes. It is a costly item of expenditure and its advantages are problematical. Nonetheless, canes along watercourses and drains may be tied up to keep them from fouling the drains and watercourse and to facilitate easy access to inside of plots to labourers at the time of watering and to keep the laterals clear.

CHAPTER VI

MATURITY IN CANE

In dealing with the growth of cane and formation of sugar we have had occasion to point out that the yield of sugar depends on the weight of cane and the percentage of sugar in the cane. Harvest of cane should, therefore, be undertaken when the cane is fully ripe. Ripening of cane varies from variety to variety and from field to field. In a carelessly grown crop it may even vary from stool to stool or from cane to cane, as when there are water-shoots or gourmandizers.

To an intelligent planter spotting out mature crop becomes easy from constant and long field observations. Deep green colour of leaves turning yellow is an indication of a change to ripening. A ripe cane, when split longitudinally, will show in the lower internodes, instead of a white appearance which normal pith will present, a glassy appearance due to air-space of the cells being filled with liquid. This turning glassy of the pith is the chief phenomenon of maturity.

Tripartite Cane Analyses

A more reliable test is the tripartite method of analyses of cane and it is the standard method in all factory farms. This consists of analysing separately for sugars, the top, middle and bottom portions of pre-harvest samples of canes from the fields.

The following is an extract from Quintus on the subject:—

"The nearer the sugar percentages of the lower and upper parts approach each other, the riper the cane is ; or rather, if these percentages approach each other the greatest possible quantity of available sugar is then present. Also the glucose percentage gives a reliable datum as to the stage of maturity, for when the cane

is not quite ripe, there is much glucose present, which, on further maturing, may be converted into saccharose. In case of over-ripeness, the sugar percentage of the middle part becomes higher than that of the lower one, and the glucose may increase through decomposition of the saccharose which had already been formed."

How near the two percentages should approach each other and how low the glucose percentage should fall, cannot be mentioned precisely, as these vary with different varieties, but experience will soon give the indications.

Pre-harvest sampling of canes from plots is essentially a field-man's job and value of results obtained will largely be in proportion to the judgment, intelligence and care used in taking samples from the field. No satisfactory method of automatic sampling of cane has yet been developed on a field scale.

Important Laboratory Terms

Below are some simple definitions of important terms used to express the results of a laboratory analysis:—

Brix.—This is the percentage of solid matter in solution as indicated by the Brix spindle or other densimeter method. The dissolved substances include sucrose or pure sugar, invert sugars such as glucose and various other organic and mineral substances.

Polarisation.—This is the approximate per cent indication of the sucrose content of a given substance or solution. The difference between the actual sucrose content and the polarisation is dependent upon the amount of invert sugar present. The greater the amount of invert sugar present the more distant from the true sucrose percent is the polarisation.

Purity.—Generally the term "Purity", without any qualification, is taken to mean the ratio: (Polar-

isation/Gravity solids) × 100. This expression is further identified by the use of the adjective *apparent*. It expresses the ratio between the solids and the sugar in a given solution; or in other words, is the per cent of Brix that is polarisation. 90% purity, for example, would mean 90% of the Brix is polarisation. Since Purity is merely the *Ratio* between Brix and Polarisation it is not affected by either the removal or the addition of water.

Cane Ratio or Quality Ratio.—This is the expected tons of cane required to produce a ton of sugar based upon the analyses of the cane juice together with an assumed set of mill conditions.

Recovery.—It is the term used to express per cent commercial sugar recovered from cane weight.

A high Brix, Polarisation and Purity resulting in a low Quality Ratio would indicate the most desirable condition of cane for harvesting.

A low Brix with comparatively high Purity might be found in wet weather. Here the quality ratio might be high due to excess of water in the cane and the purity would be the proper guide to the most favourable cane to harvest.

High Brix and low Purity might indicate dried up cane or cane that is "going back".

It is seen from such considerations as above, that a knowledge of the general conditions pertaining to a field is necessary in studying analytical results and deciding the best field to harvest next.

Cane Harvest

Difficulties in regulating harvest are not few and must be dealt with proper care and foresight. Factors that influence harvest may be grouped as follows:—

1. *Maturity of Cane.*—As far as possible and to give the best results, mature cane must be harvested. But we cannot always wait for full maturity, as in case of a factory of too small a capacity, in which case it would be necessary to begin with unripe cane to avoid loss of crushing dead canes at the end of the season.
2. In case cane is required for sets for planting, harvest should begin with immature cane, so that the top portions of canes may give good sets. Fully mature canes will not give good sets, especially if they have arrowed.
3. Situation of the field must be taken into consideration when deciding upon harvest. Distant fields or fields not easily accessible should have priority over nearby cane fields.
4. Labour, which is irresponsible and gives rise to much of the difficulties on cane-plantations, exacts a vigilant and careful handling for efficient and timely work to be done.

Difficulties of regulating harvest and supply of proper quality of cane to the factory for its most economic working cannot be over-emphasised. It requires a well-thought-out, intelligent, long-range and accurate planning and an efficient organisation for its execution.

.Sugarcane is harvested with cane-knives or bill-hooks, the cut being given right down into the soil so as not to leave any stubble visible above ground. It is common to see, in fields carelessly harvested, stubbles rich in sugar which mean loss to the factory of about 1–1½ tons of cane per acre. The cut-cane is held in the left hand and with the cane-knife the leaves are stripped by sweeping it against the stem alternately. The top 1–1½ foot of cane is chopped and the rest of the cane

FIG. 19. Sugarcane harvest.

FIG. 20. Lay-out of cane plot on land with varying contours. Sketch showing contour irrigation on different slopes. Watercourses are lines running down hill.

(*After Gilmore.*)

thrown to form a heap. Women collect the top portions separately and cover it, in convenient places, with trash, to be used later as planting material. The canes for the mill are tied into bundles of 25–30 canes each, with green tops and leaves, and heaped near headlands of plots or near cart tracks, to be removed immediately. Harvested cane should reach the factory the same day. The loss in sugar, due to inversion, by exposure to sun in the field and the loss in weight through drying are considerable and should not be allowed.

Loss in sugar and in weight of cane, etc., due to exposure in the sun, is given below:—

Number of days' exposure in the sun	Brix	Quotient purity	Glucose %	Loss of weight %	Sugar %
0	21·3	94·3	0·2	..	16·2
1	22·1	94·6	0·3	2·1	16·0
2	22·4	86·4	1·0	3·3	13·5
3	22·8	79·7	1·9	4·3	11·6
4	22·8	77·1	2·3	5·4	10·8

The above statement of analyses of cane, shows that much available sugar is lost while the weight of cane diminishes by drying.

It will be found economical to pay for the work of harvesting, stripping, bundling and heaping at convenient places for transport at so much per ton. Transport of cane to the factory is done by bullock carts or motor lorries at so much per ton-mile; weighing of cane usually being done at the factory.

CHAPTER VII

RATOON

THE plants that grow out of the underground stems of cane after harvest come under the term "Ratoon". There is a good deal of controversy about allowing ratoons to be grown as they are known to increase attack of insect pests and fungus diseases. This is found to be particularly so with the small growers, where cultivation of sugarcane is not under rigorous control. But the advantages of ratooning cannot be ignored as, in addition to low cost of production of cane, which is important (as there is saving on sets and preparatory cultivation), milling of cane can begin a month or two earlier as ratoon canes come to maturity sooner than plant canes, thus providing a longer season of working for the factory.

All varieties do not ratoon satisfactorily. The varieties Co. 419, 281, 421; H.M. 661; P.O.J. 2878 are some of the good ratooning ones. All thin canes may be classified as good ratooners. H.M. 320 is not a good ratooner as also E.K. 28. The yield of a ratoon crop, depending on the standard of cultivation and the stand, may be expected to be fairly high, being in cases as high as that of plant cane. Canes of ratoon crop yielding a higher tonnage per acre than the plant cane, are not infrequent.

METHOD OF RATOONING

After the harvest of plant cane, the trash in the plot is set fire to lee-ward (against the wind) so as to burn slowly. Proper care is needed in doing this as flying sparks might set fire to any standing ripe-cane nearby. As a precaution, about 10 feet of the plot all round must

FIG. 21. Cultivators' loaded cane carts waiting to be weighed in at the factory *weigh-bridge* (Bhopal).

Weigh-bridge extreme right.

FIG. 22. Sugarcane as it enters the rotating cane knives of the factory mills (Bhopal).

be cleared of trash and water filled in the drains to be ready for use in an emergency. All the unburnt, half burnt and rejected canes in the plot must be collected and removed from the plot and destroyed. The stubbles of old canes seen above ground must be cut back, down into the ridges, so as to allow shoots to come out fresh and not from old cane stubbles above ground. Irrigation is given as for plant cane, immediately after harvest. A fortnight later when shoots have appeared, off-barring should be done. This consists in working a mould-board plough to cut out old roots from stools as near to old stumps as possible, without disturbing them. This operation, while removing useless old roots, opens and aerates the soil, which has been compacted by repeated irrigations, helps new root development and improves the soil in general. After a week or two ammonium sulphate is given in holes at 2 cwts. per acre and if plants have grown well, earthing may be done. Final earthing up may be given after a month, when the final dose of ammonium sulphate of 3–4 cwts. is given. The rest of the treatment is similar to that of plant cane. The entire system of cultivation is intensive and is designed to avoid loss of potential growing time.

CHAPTER VIII

COST OF PRODUCTION OF SUGARCANE

It is almost impossible to give a reliable average cost of production that would apply to conditions all over the country. The soil, climate, labour and the situation of the plots in relation to factories or main markets are all circumstances that influence the cost of production. No attempt is therefore made to work out the working cost. Nevertheless, working data, bearing on different operations in growing cane, will be found in the Appendix. These figures refer to the first few years of the working of the Factory Farms of the Mysore Sugar Co., Mandya, where the author was privileged to organise cane cultivation on a large scale for factory supply. In addition, the statements of working cost of sugarcane by cultivators in other places and on State Experimental Farms are given. Labour index of requirements for the important field operations in connection with cultivation of cane, is also given. These statements, it is hoped, will be found useful.

Factory-Controlled Cane-Farms and Cultivators' Farms

In working sugar factories, the main deciding consideration is, as all know, the profit-motive. Since cost of cane is the most important item that goes into the cost of sugar production, each factory has to decide the way it can procure cane it requires under the best advantages. That the cultivator can grow and supply cane at a lower rate than that governing factory farms, which are run by hired labour and with heavy over-head charges, is too obvious. But to get satisfactory results

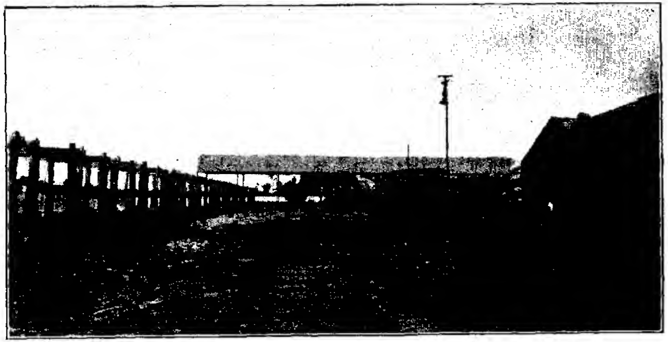

FIG. 23. Outer cane yard of the Mysore Sugar Co., Mandya, showing open cane cars, on rails, on to which the cane from bullock carts and motor trucks are transferred.

(Courtesy of the Mysore Agricultural Department.)

FIG. 24. Inner cane yard, Mysore Sugar Co., Mandya, looking towards Factory cane-carrier.

(Courtesy of the Mysore Agricultural Department.)

out of the cane supply from the cultivator requires the best organisation among the cane growers, which is conspicuous by its absence. It is found in most cases that "the cultivator works best when working for himself" cannot be applied. In Northern India factories can stabilise on a lower level of cane yields and at as profitable a level as in richer cane areas of the south. But the risk of depending entirely on disorganised, irresponsible and irresponsive clientele for proper cane supply, whose profit motive shifts from crop to crop, is a constant factor that has to be weighed, in taking decisions in the long range successful working of any sugar factory.

As could be seen from the treatise, the complexities of the problem of growing the best cane with highest yields and deliver it to the factory for milling to give the highest recovery of sugar, demand a perfect organisation and application of integrated scientific results of research at the highest level. This, in the author's opinion, will only be made possible under a highly trained and loyal technical field staff. That the sugar industry in India after fifteen years of protection still needs it, is a feature that can directly be attributed to its having failed to organise proper supply of sugarcane; as between the two phases of the industry, the extraction of sugar from cane is an industrial process, highly technical, and is easily capable of strict control. The factory-controlled sugarcane farms, therefore, should form an integral part of the working of sugar factories. The high over-head charges of the factory farms are a constant source of headache from the profit motive can be easily understood, but the solution lies in stepping up the yield of sugarcane per acre to lower cost of production and not in cutting down cost of approved methods of scientific

cultivation. These farms, it should not be forgotten, act as laboratories on the field to work out improvements continuously (as the laboratories do for sugar manufacture) for testing and selection of better canes, improving cultivation methods and working out field problems to influence higher cane yields and raise all round efficient working of farms and through them the profitable working of factories.

SUMMARY OF RECOMMENDATIONS FOR THE CULTIVATION OF SUGARCANE

1. Select land commanding irrigation, with good sub-soil drainage. If soil lacks drainage open out drains 50–60 feet apart.

2. As our soils are deficient in organic matter (Humus), grow a preliminary crop of green manure of Sann-hemp and Cowpea by broadcasting 50–60 seers of seed per acre (30 seers of Sann-hemp seed and 30 seers of Cowpea seed). A fair crop of this should give about 10,000 lbs. of green manure. Just before flowering, in $2\frac{1}{2}$ months after sowing, plough in the crop. This may be done in one operation by using a bent rail piece tied to the plough beam to push down the green manure crop. Use a log or light stone roller to press down the ploughed-in crop so that it may rot easily.

3. After ten days or a fortnight, plough the field thoroughly and deeply with a mould-board plough.

4. After a week or ten days, open deep furrows with a ridge plough along the contour, or across the slope, 3 feet apart, with water channels at 30–35 feet apart running down the slope. Make channels water-tight by pressing the sides with slush taken from the channel.

5. Select young and vigorous cane of 8–10 months' old for seed. Cut them into pieces with three eyes each, called sets. Sets from old canes of over 12 months and from arrowed canes do not give good sets, resulting in poor germination.

6. While cutting sets look out for borer-damaged and red-rot affected ones, and reject them.

7. Soak the selected sets in water for 24–48 hours. This may be done by putting them in drains and filling water by closing ends of drain. Drains must be opened out afterwards. Soaking has been found to give invariably, early and better sprouts.

8. Apply cattle manure in the furrow, at the rate of at least 10 cart-loads (5 tons) per acre, also 1 cwt. of concentrated Superphosphate (or 2 cwts. of ordinary Superphosphate) and 2 cwts. of Ammonium sulphate, and lightly mix up.

9. Spread the sets on the ridges end to end, to facilitate regular planting.

10. Let in water into the furrows to soak the furrow fully but judiciously so as not to wash out the manure.

11. Plant the sets not in the centre-bottom of the furrow, as the ground will be found to be hard and may damage the eyes, but at the bottom towards the ridge away from the centre where soil is soft. See that the eyes are at the sides. Do not press the set down as eyes may get damaged, but gently push it away into the side so that the soft soil of the ridge may drop over the set covering it. This method will facilitate, later, the workmen walking in the furrows for manuring, etc., without damaging the young seedlings.

12. Irrigate gently the furrows, without damaging the young seedlings, as often as necessary to keep the soil moist, which may be once in four or five days in gravelly soils and once a week or ten days in clayey, retentive soils. Germination will be seen in about a fortnight.

13. After a month or six weeks careful weeding in furrows should be given. Apply 2 cwts. of Ammonium sulphate in measured quantities in holes between plants (Java Method). These holes may be made with

an iron-tipped stick. Holes must not be made at the bottom of the furrow, as water of irrigation may carry it away but slightly above the water line.

14. After three months (or four months if cane growth is slow) weed thoroughly in the furrows and manure finally, interculture by bullock power and earth up with ridge plough. Final dose of ammonium sulphate of 3–5 cwts. per acre should be given now. As the price of ammonium sulphate has gone up very high, the following manurial formula is recommended instead:—

10 cart-loads of cattle manure per acre.
2 cwts. of bone-meal at planting.
2 cwts. of ammonium sulphate after six weeks of planting.
$\frac{3}{4}$–1 ton of groundnut cake at the time of earthing up.

Finish off by laying out irrigation channels at convenient distances, 30–40 feet apart, watercourses to run down the slope to irrigate furrows on the contour.

15. Irrigate regularly once a week or ten days, except during rains, so as to keep the soil moist. The optimum moisture content for sugarcane is as high as 80% of the water holding capacity of the soil.

16. Remove all shoots (tillerings) that appear after five months of planting, as these will not ripen along with others, but all the same, draw upon the plant-food in the soil. These being unripe at harvest time will, if left to grow, lower the purity of juice.

17. Prop the canes near water courses and drains, if tending to lodge, by tying up with the neighbouring clumps. No wrapping is necessary for the improved canes as they are hardy.

18. Usually 12 months after planting, cane will be ripe for harvest. Arrowing is not a sign of ripeness.

Test juice of properly sampled canes by tripartite method, for maturity.

19. The season for planting cane is after the heavy rains of North-East Monsoon, *i.e.*, from middle of November to early March and again in July and August. Avoid planting in the months of April, May, June, September and October. Where North-East Moonson is not prevalent, planting may be done in September and October.

20. So far, promising varieties of cane are H.M. 320, C.O. 419, 421, 281, 290, 360, 312 and H.M. 661, 647, 645.

APPENDICES

APPENDIX I

STATEMENT OF COST OF CULTIVATION, OF SUGARCANE PER ACRE

	Farms (Factory Controlled) 1936			Factory Farms in South India (Lift Irrigation) 1935			Cultivators' Cane in Mandya Factory area, 1935			Cultivators' Cane, 15 miles from Factory in old cane area, not for Factory supply (Bannur), 1935			Cultivators' Cane in an old cane area famous for jaggery (Goribidnur), 1935		
	Rs.	A.	P.	Rs.	A.	P.	Rs.	A.	P.	Rs.	A.	P.	Rs.	A.	P.
1. Preparatory Cultivation ..	10	13	0	17	0	0	14	0	0	32	0	0	22	6	0
2. Planting	4	4	0	4	0	0	Included in seed			4	8	0	1	15	0
3. Inter-culture and Weeding ..	13	0	0	25	4	0	10	0	0	43	0	0	21	5	0
4. Manuring	3	5	0		..			..			..			..	
5. Earthing	5	5	0		..			..			..			..	
6. Irrigation	15	8	0	65	12	0	8	0	0		..			..	
7. Harvest	38	9	0	13	0	0	17	0	0	28	0	0	11	3	0
8. Transport	52	4	0	27	0	0	34	0	0		..			..	
9. Sets	45	6	0		..		52	0	0	19	4	0	37	2	0
10. Manure	74	10	0	80	0	0	44	0	0	54	8	0	10	3	0
11. Overhead Charges	22	11	0		..			..			..			..	
12. Feed and Upkeep of Bullocks and Maintenance of Tractor ..	17	2	0		..			..			..			..	
13. General Wages	12	8	0		..			..			..			..	
14. Maintenance of Roads and Drains	4	6	0		..		4	0	0		..			..	
15. Other Charges (Stores, etc.) ..	5	4	0	0	3	0		..			..			..	
TOTAL ..	324	15	0	232	3	0	183	0	0	181	4	0	104	2	0

APPENDIX II

Cost of Feed and Upkeep of One Pair of Heavy Working Bullocks (1936 figures)

	Per month			Total		
	Rs.	A.	P.	Rs.	A.	P.
Fodder—						
Cutting and collecting green grass from headlands of plots. One woman at Re. 0–2–6 per day	4	11	0			
Jowar stalks 28 lbs. per day ..	3	12	0			
				8	7	0
Concentrates—						
Crushed horsegram 15 lbs. per day ..	15	7	6			
Wheat bran 1 lb. per day	1	2	1			
Common salt ⅛ seer per day ..	0	4	6			
				16	14	1
Other Charges—						
Shoeing charges	1	0	0			
Bullock ropes, etc.	0	8	0			
Bullock-man's wages	13	2	0			
				14	10	0
Totel per month ..				39	15	1
Cost of maintenance per pair per day ..				1	5	4

APPENDIX III

Labour Index of Field Operations in Sugarcane Cultivation

Operations	Labour required per acre				Remarks
	Men	Women	Boys	Bullocks pairs	
1. Irrigation for ploughing	2	..	..	..	
2. Bullock ploughing	2	..	..	2	
3. Passing log-harrow	1	..	..	1	½ day
3. Cross ploughing	1	..	..	1	1½ days
5. Passing log-harrow (2 pairs are used)	1	..	..	1	⅓ day
6. Picking stones	..	..	8	..	
7. Third and fourth ploughings	2	..	..	2	
8. Passing log-harrow	1	..	..	1	⅓ day
9. Passing marker	1	..	..	1	⅙ day
10. Opening furrows 3 ft. apart (Kirloskar)	3	..	..	2	½ day
11. Deepening furrows	8	..	..	..	
12. Opening plot-channels, etc.	1	..	..	1	½ day
13. Making channels water-tight	..	2	..	..	
14. Loading sets to the cart and carting them to plot for planting	4	3	..	1	
15. Carrying sets and heaping them in plots for distribution	1	2	..	..	
16. Spreading sets on ridges	..	..	4	..	
17. Applying basic manure in furrows	2	4	..	..	
18. Irrigation for planting sets	2	..	..	..	
19. Planting sets	..	4	..	..	
20. Removing excess or rejected sets	..	..	2	..	
21. Covering exposed sets	..	..	2	..	

22. Irrigation (10 upto final earthing)	2	..	..	..	each
23. Borer-control—					
Preparing trash bundles	1 man prepares 60 bundles				
Fixing bamboo pegs for heaps	1 man for 10 acres				
Cost of bamboo 0–1–0 per acre	..	..	..	..	
Collection of moths from trash heaps every morning, and egg-masses, removal of dead hearts for 3–4 months from planting time (75 times)	..	..	2 boys for 3 acres		
Light earthing	1 man and 1 pair bullocks if plough is used, or 8 boys				
24. Carting manure	2	..	..	1	
25. Applying manure	1	..	2	..	
26. Weeding (3 times; 5, 8 and 10 weeks after planting at 6, 8 and 10 women each)	..	..	..	..	
27. Filling gaps	3	8	..	..	
28. Flood-irrigation for final earthing	3	..	..	..	
29. Inter-ploughing in cane crop	1	..	..	1	¼ acre
30. Passing heavy ridger for earthing	3	..	..	2	
31. Lifting buried plants	..	..	2	..	1 acre
32. Finishing and laying irrigation channels	6	..	..	..	
33. Irrigation to earthed cane till harvest about 40 irrigations at 10 days' interval at 2½ acres per man-day	..	..	..	..	
34. Removing late tillers, tying cane near water and drainage channels	4	..	..	..	1 acre
35. Turfing irrigation channels (mains)	3	..	2	1	80 running yards in a day
36. Harvesting—					
(a) Cutting cane and topping	30	..	..	..	Crop of 50 tons per acre
(b) Stripping and bundling	..	45	..	..	
(c) Heaping them near roadside	..	30	..	..	
(d) Loading cane to lorries	6	..	..	..	
37. Cutting sets	1 man cuts 10,000 sets a day				
Selection of good sets	..	1 woman can sort 8,000–10,000 sets			

APPENDIX IV

NITROGEN VALUE OF FRESH GREEN MANURES

Name of Green Manure	Nitrogen %
Sunnhemp (*Crutolaria juncia*)	0·89
Honge leaves (*Pongamia glabra*)	1·16
Honge stems	0·17
Thangadi leaves (*Cassia auriculuta*)..	1·05
Thangadi stems	0·35
Calotropis gigantia (Yekka)	0·42
Lantana leaves	0·88
Cowpea (*Vigna catiang*)	0·77
Avare (*Dolicos lab lab*)	0·72
Black gram	0·86
Green gram	0·83
Horse gram (*Dolichos biflorus*)	0·91
Gingelly plant	0·88
Ugane (vine and leaves)	1·21
Cowpea roots	1·10
Avare roots	1·45
Sunnhemp roots	1·10
Green gram roots	1·84

—*Courtesy of the Department of Agriculture, Mysore.*

APPENDIX V

COMPOSITION OF SOLID AND LIQUID EXCRETA OF SOME FARM ANIMALS

Name of Animal	Excreta	Proportion by weight %	N %	P_2O_5 %	Potash %	Water %
Horse ..	Solids	80	0·55	0·30	0·40	75·0
	Liquids	20	1·35	Trace	1·25	90·0
Cow ..	Solids	70	0·40	0·20	0·10	86·0
	Liquids	30	1·00	Traces	1·35	91·5
Sheep ..	Solids	67	0·75	0·50	0·45	57·6
	Liquids	33	1·35	0·05	2·10	86·5
Pig ..	Solids	60	0·55	0·50	0·45	76·0
	Liquids	40	0·40	0·10	0·45	97·5
Hen ..	Excreta	..	1·00	0·80	0·40	..

—*Courtesy of the Department of Agriculture, Mysore.*

APPENDIX VI

Plant-Food Contents of Oil-Cakes

Name of Cake	N %	P_2O_5 %	Potash %
Castor cake	4·37	1·85	1·39
Cocoanut cake	3·02	1·90	1·62
Cottonseed cake (undecorticated)	3·99	1·89	1·62
„ (decorticated)	6·41	2·89	2·17
Dhupaka cake	1·13	0·21	..
Groundnut cake	7·29	1·53	1·33
Jambo cake	4·95	1·65	1·90
Karanj cake	3·97	0·94	1·27
Linseed cake	5·56	1·44	1·28
Mahua cake	2·51	0·80	1·85
Neem cake	5·22	1·08	1·48
Niger cake	4·73	1·83	1·31
Rapeseed cake	5·21	1·84	1·19
Safflower cake (undecorticated)	4·92	1·44	1·33
„ (decorticated) ..	7·88	2·20	1·92
Sesame cake	6·32	2·09	1·26
Undi cake	3·63	1·53	2·05

—*Courtesy of the Department fo Agriculture, Mysore.*

APPENDIX VII

Improved Methods of Preparation of Farmyard Manure and Farm Composts

Two methods for preparing farm manures which are improvements over the present ones followed by raiyats are described below. These are (1) the Trench method and (2) the Plastered heap method. The advantages of the methods now recommended are: (1) reasonable saving in labour, (2) better conservation of moisture which facilitates proper decomposition of the materials, (3) the manurial factors are preserved better and thereby the quality is improved, and (4) a larger quantity of manure is recovered due to prevention of losses under conditions of unregulated decomposition.

Trench Method

(1) Depending upon the size of the farm, trenches of the following sizes need to be excavated:—

No. of Cattle maintained in Farm	Size of Trench		
	Length	Breadth	Depth
	ft.	ft.	ft.
2–4 animals	20	4	$3\frac{1}{2}$
6–10 ,, ...	25	4	$3\frac{1}{2}$
15–20 ,, ...	30	5	$4\frac{1}{2}$

The trenches should preferably have sides sloping inwards and the bottom also sloping to one end. Four such trenches will suffice for a whole year. While the manure in two trenches mature, the other two can get filled up. Earth bunds should be raised at the top all round the sides of trenches to prevent rain water from rushing in.

(2) Trench filling is commenced by taking the first three feet length from the shallower end. A few split bamboos fixed vertically can mark this distance from the end.

(3) Mix the day's collection of dung, litter, cattle bedding and urine and dump loosely within the 3 feet space in trench and level up same.

(4) Cover the top with a thin layer (about 1 inch) of urine earth scraped from the cattle-shed. Where urine earth is not available, ordinary dry earth can be used.

(5) Any bone-meal or charred bones available on the farm can be put on the top of the refuse layer. This would enrich the manure in phosphoric acid found usually lacking in cattle manure.

(6) The succeeding day's collections are dumped over the previous day's lot, levelled up and covered with a thin layer of earth as before. This is repeated for a

week or more, till the top level rises to about one foot above ground level. The top is then smeared over with an inch thick mud plaster. This can be effected easily by spreading a layer of earth, sprinkling with water and smearing with the hand.

(7) The next 3 feet portion on the vacant side is taken up and the filling continued as before. The heaps are raised in sections of about 3 feet at a time till the whole trench is filled up.

(8) If after a month or so, the top level sinks below ground level, fresh refuse and dung may be added to raise the level a foot above ground level. This precaution helps to divert the excess rain water during rains.

(9) The material in the trench need not be given any turnings and usually no waterings will be necessary. The manure is generally ready in about 4–5 months.

Plastered Heap Method

This method is preferably adopted in places where the water table is high and it is not possible to prevent water from rising up the bottom of trenches.

(1) Each day's collection of mixed refuses dung, urine, etc., is dumped to form a square heap of about 3 feet sides. This is covered over with a layer of dry or urine soaked earth.

(2) Subsequent days' collections are dumped on above heap and the heap built up to a height of about 4 feet and covered up with a layer of earth.

(3) A second square heap is raised adjoining the first heap so that one side is common to both. This heap is also built up to the same height.

(4) The third and fourth heaps are similarly built up so that one large square heap of about 6 feet sides is formed.

(5) The outer sides of the large heap are drawn up to form a dome-shaped mound and this is plastered with earth and water or earth-cowdung paste.

(6) In ordinary cases where dung, mixed refuse and urine are collected and used, no turnings to the heap need be given, and the manure would be ready in 3–4 months' time. However, where large proportions of more resistant type of vegetable refuse low in nitrogen, like sugarcane trash are used, it is preferable to give a turning after one month, with watering or addition of more dung and urine. The heap should be plastered over again with earth so that the moisture and heat produced may be conserved and better decomposition effected.

—Courtesy of the Department of Agriculture, Mysore.

APPENDIX VIII

Table of Measures and Weights

A. Measures

Inch = 0·02539954 metre.
Foot = 12 inches = 0·304794 metre.
Kilometre = 3,280 feet 10 inches = 0·62137 mile.
Metre = 39·37 inches.
Mile = 1,609·315 metres = 8 furlongs = 1,760 yards.
Yard = 0·9144 metre = 3 feet.
Acre = 4840 sq. yards = 4,046·71 sq. metres.
Bigha (Bihar) = $\frac{5}{8}$ acre.
Bouw (Java) = 1·747 acre = 7,096·5 sq. metres.
Hectare = 10,000 sq. metres = 2·471 acres.
Koh (Formosa, Japan) = 2·45 acres.
Square metre = 1,550 sq. inches.
Gallon (Imperial) = 4 quarts = 4·545963 litres.
Gallon (American) = 0·832 imperial gallon = 3·785 litres
Cubic foot of fresh water = 6·25 gallons and weighs 62·5 lbs.

B. Weights

Ton (English and statistical) = 20 cwt. of 112 lbs. avoirdupois or 27·2 maunds (Bengal, Br. India). of 82$\frac{2}{7}$ lbs. avoirdupois = 2,240 lbs. = 1,016·047 kg.
Ton (United States or short ton) = 2,000 lbs. = 906·08 kg.
Ton (Metric) = 1,000 kg. = 2,204·60 lbs. avoirdupois.
Maund (Bengal, Br. India) = 40 seers = 100 lbs. troy = 82$\frac{2}{7}$ lbs. avoirdupois = 37·3242 kg.
Maund (Mysore) = 28 lbs.
Picul (China, Japan) = 133 lbs. = 60·45 kg.
Picul (Java) = 136·16 lbs. = 61·761302 kg.

Some Indian Terms

Rupee = 16 annas = 192 pies = 1*sh.* 6*d.*

Lakh or Lac = One hundred thousand, *i.e.*, 1/10 of a million, *i.e.*, 1,00,000.

Crore = 10 millions, *i.e.*, 1,00,00,000 or 100 lakhs.

Gur or Jaggery.—It is unrefined brown sugar. It is prepared in different forms Cubes, lumps, powder and in semi-liquid form. It contains from 60–85% of sucrose, and may be said to be crude hard-boiled massecuite. Gur constitutes nearly 76% of the total sugar of various kinds produced in India, factory sugar making about 21%.

Khandsari Sugar.—It is known generally as khand. It is powder sugar of white to brown colour. Its sucrose content varies from 96–98%, while factory sugar has from 98–99%. Its production is about 2% of all kinds of sugar.

Adsali.—The term is used in Bombay Presidency for the sugarcane crop which is planted in the months from June to August and harvested from October to January in the following year.

Co.—This prefix to a variety of cane shows that the variety was bred at Coimbatore—Co. 419, 421, etc.

H.M.—This prefix to a variety of cane shows that it was bred in Hebbal (Mysore)—H.M. 320. I.C. canes are those that were bred in Irwin Canal Farm near Mandya, Mysore.

P.O.J. 2878, E.K. 28 are the canes that were introduced from Java.

APPENDIX IX

Soil Fertility Studies with Mauritius Soils

The author notes that although soil fertility is one of the most important subjects in the realm of agricultural science, and one in which a tremendous amount of work has been done, there is surprisingly little agreement as to the best methods to be employed. This is, perhaps, because different workers are engaged on very varied soil types. He therefore doubts whether standardized methods, applicable to all soil types, will ever be evolved. However, he offers an outline of methods used in Mauritius, which include field experiments, chemical laboratory methods, and physiological methods in field and laboratory, with chief emphasis on field experiments which should be supplemented with chemical and physiological tests. Phosphate fixation and the matter of exchangeable bases should be duly considered. Chief among the physiological methods studied was the analysis of juice. Some authors have stated that 0·03 per cent. of P_2O_5 in the ripe cane juice may be taken as indicative of a sufficient supply in the soil; but that this figure is not universally applicable is shown by the fact that different cane varieties, grown under identical conditions and replicated as many as 36 times, may show very marked differences in their P_2O_5 content.

Note.—Most of the complexities, uncertainties, and irrelevancies of present day soil science disappear when the agrobiologic concept of "normal soil" is held in view.—*Ed.*

—From "Facts about Sugar," April 1936.

APPENDIX X

IMPORTANCE OF THE PHYSIOLOGICAL REACTION OF COMMERCIAL FERTILIZERS

In making up commercial fertilizers, the manufacturers of these commodities naturally use the cheapest accessible materials, and as ammonium sulphate is now the cheapest available form of nitrogen, most commercial fertilizers contain this material without accompanying materials that will neutralize the sulphuric acid that is set free when the plants absorb the ammonia. The result is that soils persistently fertilized with ammonium sulphate become strongly acid, with a resultant damaging effect on the crop. It is recommended that farmers insist on fertilizers in which at least part of the nitrogen is in the form of calcium nitrates, or that other acid-neutralizing substances be present.

—*From "Facts about Sugar," April* 1936.

APPENDIX XI

PLOT TECHNIQUE IN THE TESTING OF SUGARCANE VARIETIES

In the testing of new cane varieties, a first question is that of suitable plot size. It has been shown both in Hawaii and in Java that the error of the individual plot decreases as the plot size is increased. For light crops of 50 tons per acre, 1/15 to 1/20 acre may be satisfactory, but 1/10 or 1/5 acre is preferable for 75 ton crops. A reduction in plot size with corresponding increase in number of plots may reduce the average error, but if this principle is carried too far, the result may be entirely misleading. For instance, H. 109 is a cane of relatively slow growth in the early stages but in the end may give

as much as 15 tons of sugar per acre in 24 months; on the other hand, U.D. 110 has great growth vigour in the early stages but its final yield is considerably below that of H. 109. When these two varieties are tested side by side in small plots U.D. 110 starts off quickly and maintains its lead through the crop, due to the fact that its strong roots invade the soil of its rival (border effect), whereas if the plots are large enough to minimize the border effect, the inherent superiority of H. 109 comes to the front.

For testing seedling canes, of which only a small supply of planting material is usually available, the authors prefer a systematic layout in which the seedling plots alternate with plots of the standard variety, and they discuss at length the reasons why this arrangement is preferable to the Latin square or randomized system. They also take occasion to discount the view held in some quarters that the technique which gives the lowest calculated error and thus the highest odds is necessarily the one to be preferred. High odds cannot in themselves insure against incorrect and misleading average differences, due to soil heterogeneity and border effects.

—*From "Proceedings of 5th Conference of International Society of Sugarcane Technologists," Brisbane*, 1935.

APPENDIX XII

Systems of Cultivation

There is one further aspect which has a bearing on the present discussion. Whereas, in the sugar industry, organization is by independent units, it is inevitable that a policy of "each for himself and the devil take the hindmost" should prevail. Each unit is compelled to place its own balance sheet in the forefront and human

instinct turns to increased production as the most likely path to that desirable result. The prominence given to record yields is but one sign of the prevalence of that instinct. Frequently, perhaps generally, instinct is a sure guide in this matter; but it is not always so and the alternative, reduced production, is worth a few minutes' consideration. The test of industrial success is here profit, and profit is no absolute measure. It is the difference between the cost of unit production and the value obtainable for a unit of the product. It is not linked with a high out-turn though it tends to be so linked when overhead charges are disproportionately large. The urge to high production can be carried too far and it may be found that a lower standard of production will prove the most profitable even for the independent units.

These are platitudes, but they have their application to the present case. The largest individual charge in sugar production is for labour and the most obvious means of cutting down labour charges is an application of mechanical labour-saving devices. On the farm and the plantation, mechanism has advanced with such rapid strides that labour replacement has proceeded far without any accompanying diminution of out-turn; of this the Hawaiian sugar industry offers a good example. But this is not the only means of cutting down labour charges; another and, perhaps, equally efficacious way is a reversion to peasant cultivation. It is a possible method, for it has been adopted with success, notably in the Fiji sugar industry. Peasant cultivation supplies cane to the factory at a rate lower than that of cane grown on the plantation by paid labour; but this is not the only or, perhaps, the main point. Yield under a peasant system is invariably lower, generally considerably lower, than

yield under a plantation system. It is possible, therefore, that production might be stabilized at a lower, but more profitable level. Whether it will be so or not is a question which each unit must decide for itself; the answer may very well differ in different cases, for there are a number of considerations which point in the contrary direction. The factory is designed as a balanced unit to carry a certain weight of overhead charges against a certain production and it may be that, at a lower standard of production, these overhead charges will prove too onerous. The benefit will be lost if the result is merely an increased area of cane sufficient to compensate for the lower yield. It must be pointed out, however, that the same argument derived from overhead charges applies in the case of reduced output as the result of control or quota. Again, it is not every cane growing country which possesses an adequate population with the suitable mental equipment. Mentality is important and it is not everyone who will agree with BEAULIEU in his view that the peasant works best when working for himself and with the universal applicability of that view. Lastly, peasant cultivation requires to be organized, an aspect which need not be discussed at length here since it has been discussed in an earlier issue.

Sugarcane is but one of the crops grown in the world and it may help to bring the above discussion into perspective, if it concludes with a brief account of the more general question. Attention has been drawn both to the potential yield of crops in general and to the small proportion of that potential yield which is now secured. It requires little imagination to visualize in general outline what must inevitably happen if only a fraction of that increase is realized in practice and the product thrown on to a relatively inflexible food market—a struggling

industry—and a host of individuals thrown on to a labour market already overcrowded as the result of mechanization in industry. Most of the increased production of the last fifty years has arisen from the opening up of virgin lands—a process which has by no means reached its limits—and sufficient has been said to show that the application of scientific method, although so recently applied, is going far towards making a realization of a perceptible part of that increase possible. It requires little further stimulus to create a situation where production will exceed any possible increase of consumption. It is urgently desirable that all practical means of keeping the population on the land should be adopted and in peasant cultivation will be found the readiest means of achieving this object. In the sugar industry, no less than in others, remedial measures are likely to be ineffective unless these more fundamental world forces are borne in mind.

—*From "International Sugar Journal," April* 1935.

APPENDIX XIII

Wet or Dry Planting of Cane

A series of experiments was undertaken in an effort to settle the much-debated question of wet *versus* dry planting of cane. By wet planting, is understood, flooding the trenches with an excess of water; dry planting refers to planting in soil with a normal moisture content. The results of this investigation did not show a pronounced difference in favour of the one method above the other; while there are slight differences, no general conclusions are warranted.

—*"International Sugar Journal," April 1935.*

APPENDIX XIV

WATER AND CANE RIPENING

This work was undertaken to determine whether formation of sugar occurs when water is withheld from cane in the later stages of growth, with the general idea of forming an opinion as to whether the planter is justified in stopping irrigation three months before harvest. The results, which are regarded as merely preliminary, indicate that there is a greater synthesis of sucrose in the blades of cane plants supplied with water than in those deprived of water.

—"*International Sugar Journal,*" *April* 1935.

APPENDIX XV

RELATIONSHIP BETWEEN SOIL MOISTURE AND CROP GROWTH

A field experiment was carried out to investigate the moisture contents of soils that would maintain the maximum rate of growth of sugarcane, making allowances for soil type, variety of cane, and time of planting.

In every case the optimum moisture content was found to be very close to 80 per cent. of the water-holding capacity of the soil. Aside from this requirement, the maximum growth rate was found to vary directly with the atmospheric temperature; while the latter remained at 80° or higher, favourable moisture conditions gave rise to rapid growth. At 75°–80° the maximum rate was reduced by about 50 per cent., and further diminutions were noted when the temperature fell below 75°. The growth rate naturally slackened as maturity was approached.

Varying soil textures did not affect the growth rates, the extreme soil types producing similar growth rates

as long as the moisture contents of the soil were maintained. All varieties maintained a high maximum rate of growth in the hot season, but in the cooler season Badila had a much lower rate than H.Q. 426 or B. 208 for the same soil moisture figure. Plant and ratoon crops of H.Q. 426 and B. 208 gave similar results, indicating that rate of growth is independent of the class of cane.

The results show generally the need for intensive irrigation in the hot months. In most cases it appears that 10-day intervals would have been none too short, while in the cooler months 4-weekly irrigations would often suffice to maintain what growth does take place.

Note.—This is another experimental confirmation of the fact that in the growing of crops in general, and of the sugarcane in particular, nothing matters very much except a suitable temperature, an adequate supply of soil moisture, and sufficient plant food in the soil. Given these three basal conditions, any crop can but succeed. Contrary to what is alleged by some professional soil surveyors, the texture or physical nature of a soil is negligible where it is at all possible to govern the water and plant food supply. It does not matter much, even, how much moisture the soil can hold, provided only that it is kept nearly full.—*Ed.*

—"*Facts about Sugar*," *July* 1945.

APPENDIX XVI

The Agricultural Aspect of the Response to Depression in the Cane Industry

The prolonged depression in the sugar industry is primarily due to an excess production which is an aftermath of the war (first War, 1914-18). The large reduction in the area under beet during the war period stimulated a correspondingly large increase in the area planted to cane which has furnished a competitive supply, when

economic nationalism dictated the re-establishment of the beet industry. With this redundancy of supply thrust on to a restricted free market, the main trouble of the industry is economic and the ultimate solution must be found in international agreement. This is a complex problem, as experience is demonstrating, in view of the number of national interests involved and, meanwhile, the individual units have to seek salvation as best as they can. For the industry is organized on a basis of financial units which are independent or, less commonly, form loose combinations for such specific objects as the representation of their common interests to Government, marketing or research. To units so situated, finance is the dominating consideration and each is compelled to follow the individual course best calculated to ease its own situation. In the absence of an all-embracing international agreement, the present situation is being met by national action in protection of the home industry, by combined organized marketing, by organization of production and by research. It is not proposed to consider here the first two of these; their primary object is to secure the maximum return for the unit product. The object of the two latter is complementary, to secure that unit of production at the minimum cost, and it may be of interest in view of the forthcoming meeting of the International Society of Sugarcane Technologists, to review briefly the activities of the various cane-growing countries in this direction.

The production of sugar is a dual process, the raising of the crop and the extraction of sugar from the crop when raised. The latter is highly technical, but it is essentially an industrial process in that it is capable of control. The amount of sugar entering the factory is calculable and the efficiency in recovery readily demon-

strable. The various stages of extraction are mechanically regulable and the entire process has now been so closely studied, that in most factories, there is but small scope for adjustments which will materially reduce cost. The larger field for economy now lies in the production of cane. This is not so readily brought under control and, only in recent years has this aspect been subjected to intensive study. Results, however, are already demonstrating the truth of the statement that here is to be found the widest scope for economy.

Openings for Economy

The test for economic production is the cost of mature cane delivered at the factory. That cost is a complex of a number of factors which are to a considerable extent independent. These may be summarized under a number of heads, cost of cultivation, of manures, of irrigation where this is provided, of harvesting and of transport on the one hand; and on the other, yield of cane and quality of juice. Into the cost of the former may enter a certain capital charge, as for machinery or canalization, but here the dominating cost is labour. It is this dominance of labour which has led to the adoption of those varied systems of cultivation which differentiate the scattered cane-growing countries and it is this human element which has dictated much of the change of system which has taken place in recent years. Accompanying the general trend of higher cost of manual labour, there has occurred a lowering of the cost of the use of mechanism and a vast extension of the adaptability of mechanical appliances to serve different functions. The scope for the substitution of human labour by mechanism is rapidly extending and the study of the labour problem becomes at once one of major importance.

Three factors have militated against the study of crop production in the past. So obvious was the dependence of yield on the meteorological conditions and on disease, both of which seemed beyond the control of man, that the fatalistic attitude which prevailed till recently, and still to some extent prevails, is readily understood. Further, the variations from season to season are such, that no rule of thumb system could be laid down as in a factory process and the seasonal modifications of practice necessitated by these variations required more than a little skill in application. Lastly, for the correct understanding of the local factors which determine the particular practice to be adopted, a highly trained technical staff was required and this lay beyond the means of most individual units. In most countries these difficulties are at least partially overcome. A realization of the potentialities of increased crop production is growing and they are being rapidly developed by combination or other organization for the purpose of carrying the overhead charge of such staff.

Labour

The particular form assumed by the labour problem is a matter of locality, but behind this, as determining the system of production prevalent, is, in all cases, the more fundamental question of land. As each cane growing country was opened up, the abundance of the local indigenous population largely dictated the system adopted. Where the population was dense and free land unobtainable, as in India, a peasant system had, perforce, to be adopted; where land was available, the tendency has been to a plantation system run directly by the manufacturing interests with hired labour. Nor must history be neglected in this connection. In the earlier years

a shortage of labour could be made good by importation of slave labour as in the West Indies, to be followed by a system of imported and indentured labour, in Fiji, the West Indies and Hawaii, when slavery was abolished. A further complication arose when, as the result of the development of the central factory and the inefficiency of the smaller plantations as economic units, centralization of production became necessary. Here the reaction in some cases, as in Jamaica and, as a passing phase, in Fiji, was to estates run on the plantation basis but not controlled by the factory. It is a system also found in South Africa and Cuba. The industry is commonly based on low paid labour, whether indigenous or imported, but Australia offers a special case where the entire cultivation is performed by white labour.

In these varying circumstances the response to the need for economy has not been identical throughout. The obvious dominating factors have been the rising cost of manual labour and the progress of mechanical application to farming operations. The natural and expected outcome, a substitution of the former by the latter, is being attempted in most countries but especially in those which suffer from a shortage of labour. Particularly is this substitution found in Hawaii; in Australia it appears to offer an easement of the situation though the smaller unit here makes the problem more complex. But it is not the only reaction. In Fiji the situation has been met by an intensive reversion to a peasant system and, to a lesser extent, owing to the specialized nature of its product which dispenses with the central factory, in Barbados. Here economy arises as the result of the replacement of a paid labour force by family labour paid by results. The cost becomes a known quantity directly dependent on the amount of cane or sugar deli-

vered. Typical of this form of production is a reduced yield per acre but, provided the total production is adequate, this does not affect the financial aspect.

That the search for economy has led in such divergent directions is a consequence of the local conditions. It is more than probable that, when viewed from the narrower aspect of the individual producer, each is right in its particular sphere. Whether both developments are equally desirable from the wider aspect of the country as a whole is more debatable. Labour throughout the world is not only becoming dearer but is demanding greater independence. Further, it does not find its sole market in the sugar fields. There appears to be scope in most countries for a deeper study of the labour problem than has yet been accorded and study of the problem in Trinidad which has recently appeared is of more than passing interest.

Cultivation

Though, as in the case of planting and harvesting machines which have been developed in Hawaii and Australia and of the planning of irrigation systems as in Hawaii, it is true to say that the impetus towards mechanization in the cane fields is a direct response to the labour position, this is not by any means the only stimulus. More efficient ploughing as by the "gyrotiller" and heavy tractor-drawn ploughs, better control of weeds and inter-culture partly justify the use of mechanism in an increased crop. There is here raised a question of soil conditions which has required physico-chemical investigation and, in most cane-growing countries, the newer methods of soil analysis have been recently applied with great practical benefit. Particularly noteworthy are the investigations which have led to a detailed classification

of the soils of Java and the recent researches showing the marked change which has taken place in the soils of British Guiana as the result of cultivation. There is being collected by these means a mass of information on the constitution of the soils which is of the utmost value in its application to soil treatment.

Manuring

The above mentioned work has a dual bearing. On the one hand, the physical constitution of the soil is laid bare and a basis given for determining the best cultural operations to adopt; on the other, the chemical constitution, leading up to the practice of manuring. Here, perhaps, the outstanding question is the relative advantage of artificials and natural manure as represented by pen manure. Hawaii has long been the protagonist of the former but recent work in the West Indies and Mauritius, the home of pen manure, is producing proof of the efficiency and economy of artificials.

Cane Breeding

Not the least of the activities which have led to the increased production of recent years, is that which has been directed to plant improvement. Following the early work in Java and Barbados, intensive study of this aspect of the problem has been undertaken in Java. India followed closely with the establishment of the cane breeding station at Coimbatore where Barber first developed the idea of the direct cross with *S. spontaneum* and later, Venkataraman has succeeded in producing a sorghum × cane cross. If the marked development of the Indian sugar industry is a direct response to her tariff policy, it is certain that this development could not have matured without the concurrent work of Coimbatore. In all the warmer countries where cane sets viable seed,

the raising of cane seedlings in their thousands is now effected and is proving not the least important function of the research station. Space does not admit any detailed reference to the many subsidiary problems arising from this line of investigation, the detailed study of chromosome numbers, the technique of the retention of the viability of pollen, the determination of parental influence and so on.

Disease

If the primary aim of the work, just referred to, is the increase of crop production, there is no less important field of work of which the primary aim is the prevention of a reduction of yield due, in most instances, to disease. It is not too much to say that it was the incidence of disease in virulent form which gave in the first instance the impetus to scientific investigation and particularly to breeding. This is true of Java and the West Indies in last century and, more recently, of Louisiana. Here, again, each country offers a particular problem arising from the specific organism responsible for the disease and much of the recent work is directed, as in Australia, to ascertaining the degree of resistance of new seedlings to the most important local diseases.

Other promising lines of defence are the institution of strict quarantine (the West Indies, Hawaii and South Africa), the control of the varieties permitted (Australia and South Africa) and biological control. The latter has been most successful under the favourable conditions of insular Hawaii, but is being pursued with vigour in the West Indies and Lousiana in efforts to control the borer, and in Mauritius.

Reference must also be made to the progress which is being made where exists poor growth, amounting in cases, to a definite pathologic condition but not asso-

ciated with any specific organism. The solution of these cases is being sought in the improvement of the physical conditions of the soil.

Quality of Juice

The ultimate value of a cane lies in its capacity to yield a high return of sugar which is dependent not only on the yield of cane but on the amount of juice in the cane and the amount of sugar in the juice. This last factor may be characteristic of the variety, and many seedling canes with an excellent capacity for yielding high tonnage of cane have had to be discarded owing to the low quality of the juice. Again other varieties, notably the well-known P.O. J. 2878 cane, have proved unsuited to certain areas owing to their incapacity to mature within the growing season. The determination of quality of juice, therefore, is second in importance only to tonnage of cane. To meet this point the selection of seedlings in the Philippines is based on a Brix × weight rating. For the rapid determination of juice quality the use of the hand refractometer is extending.

Conclusion

The striking feature of all the above developments, which, if not arising from, yet owe their intensive pursuit to the depression, is that the units of production are each severally seeking their salvation in the struggle for survival along lines which inevitably lead to increased production and, in consequence, can only intensify and extend the period of depression. It is a response which is inevitable and one which finds its counterpart until consumption capacity expands must, therefore, be sought in international agreement or in the discovery of some alternative use for the products of cultivation.

—"*International Sugar Journal*," *July* 1935.

APPENDIX XVII

The Top-Bottom Ratio Method for Determining Maturity of Cane

The authors have established the fact that while sugarcane is growing the lower internodes contain more total solids (as shown by refractometric tests) than the upper internodes, but that, as maturity is approached the ratio of solids in top and bottom becomes equal to 1. On this basis it is possible to decide when a cane crop is mature, provided the sampling is truly representative.

—"*Proceedings of International Society of Sugarcane Technologists,*" 1935.

APPENDIX XVIII

Soaking Seed Cane before Planting

Two experiments were made to investigate the effect of soaking on the germination of cuttings and on the final yield of cane, both plant and first ratoon. There were five treatments: (1) soaked in a saturated solution of lime; (2) soaked in a saturated solution of lime containing also one pound of magnesium sulphate per 50 gallons; (3) soaked in a complete nutrient solution containing all plant foods; (4) soaking in water alone; (5) no soaking. In one experiment the soaking was for a period of 8 hours, in the other 16 hours.

In both experiments the yield of cane from the seed cane that had been soaked in (1) the lime, and (2) the lime and magnesium sulphate solutions, was significantly better than the yield of cane grown from seed cane that was not soaked, and also better than from the treatments (3) and (4). There was no significant difference between

soaking in lime solution alone, and lime solution *plus* magnesium sulphate. Hence preference is given to the method of soaking in saturated lime solution, because it appears to be the simplest. Both experiments were extended to include the first ratoon crops from all treatments. In the plant cane the increase of yield from the cane soaked in lime water was about 25 per cent., in the ratoon crop about 17 per cent.

The author has made some investigations with a view to finding an explanation of why soaking the seed pieces results both in a better germination and a larger yield of cane. It was first thought that the soaking would initiate a rapid hydrolysis of sucrose, which would speed up the germination process. It could not be shown that soaking had any marked effect on the rate of hydrolysis. It was then thought that the nature of the solution would have some effect on the amount of water absorbed by the seed pieces. By experiment it was found that the pieces actually absorbed significantly more water from the lime solution than from pure water; and this appears to provide answer to the question. The pieces that have been soaked in the lime solution have absorbed more moisture, and therefore germinate faster when planted; this rapid germination assures a more vigorous growth.

While soaking in the lime solution resulted in an increased percentage of germination, there was still a certain number of failures. By a special investigation it was found that the most uniform stands (lowest percentage of blanks or misses) were obtained when the planting material was taken from young cane, or the top portions of old cane; this means that the best planting material is that containing the largest percentage of invert sugar. Obviously, when such material is soaked

in lime water, one condition will be provided that will help to give the best stand and the largest yield.

—"*Facts about Sugar,*" *December* 1935.

APPENDIX XIX

THE FUNDAMENTAL PRINCIPLES OF CANE PAYMENT

The basic principle underlying any modern scheme of cane valuation is that the grower and the miller are two partners in a joint enterprise for manufacturing sugar from sugarcane. For this reason, the price paid by the miller to the grower for his cane is not governed solely by competition or the rigorous laws of supply and demand, but is almost universally held to depend on the price received by the miller for his product. How this can be done in the fairest and most expeditious manner is the problem considered in this paper. The four methods of payment in use in various parts of the world are passed in review. These are: (1) payment for each ton of cane delivered at a price proportional to the value of sugar; (2) payment for each ton of sucrose in the cane (modified by various other factors) at a price proportional to the value of sugar; (3) payment for each ton of sugar estimated to be recoverable from the cane as delivered, at a price corresponding to the value of sugar; and (4) payment for each ton of sugar estimated to have actually been recovered from the cane delivered, at a price corresponding to the value of sugar. Method (1) is a very primitive one and can be considered obsolete. Method (2) is somewhat (but not much) better; it is the method used in South Africa. Method (3) is an advance on method (2) and is used in Australia. Method (4) is the commonest method in vogue in most parts of the world.

Whether method (4) is better than method (3) or *vice versa*, is a subject for argument. In favour of method (3) it may be argued that it places responsibility for efficiency of factory operations on the miller and not on the grower, who then has no occasion to question factory methods. On the other hand, method (4) eliminates many arbitrary considerations that enter into any method of assessing recoverable sugar. It has the advantage of being the commonest method; growers in most parts of the world are familiar with and have confidence in it, and it will doubtless continue to be used. The mathematics of computing the grower's share under these methods is discussed at considerable length. There is no intention on the part of the author to recommend any particular formula, but merely to outline the general principles which should be followed in devising any payment scale.

—"*Proceedings of 5th Conference of International Society of Sugar Technologists,*" *Brisbane,* 1935.

APPENDIX XX

Some Plant-Food Values in Molasses and Filter Cake

Molasses and filter press cake are two by-products of the sugar industry which are sometimes diverted for use as fertilizers (when they are not thrown away). Their value as fertilizers is not yet settled to the satisfaction of everybody. The author has undertaken to study the question by means of pot tests, using Sudan grass as indicator plant. The results, while not regarded as definite, show that the effect of either molasses or filter cake varies with different soils, the dominating factor appearing to be the available nitrogen content of the soil that received the application; it seems questionable

to use them on such soils if the object is to supply nitrogen. On the other hand, it seems that the potash and phosphate contents of these materials are equivalent to the corresponding nutrients in commercial fertilizers, but here it must be considered that their use may be attended by the disappearance of some of the nitrogen in the (poor) soil due to the locking up of some of this original nitrogen by bacteria that feed on the added carbohydrate materials. It is not certain that the nitrogen thus locked up will eventually be returned.

Note.—The implication seems to be that when molasses and filter cake are used on poor soils, they should be accompanied by extra nitrogen in some other form.—*Ed.*

—"*Hawaiian Planters' Record,*" *Vol.* 39, 1935.

APPENDIX XXI

Utilization of Waste Molasses

In most cane-growing countries a distillery is attached to the sugar factory, which every year produces appreciable quantities of yeast as a fermentation by-product. The author proposes that this yeast be recovered and composted for use as a fertilizer. For this purpose settling basins for the slop should be installed; the accumulated sediment is sprinkled over cane trash and other organic refuse, and layered in piles in the usual manner of making compost heaps. In this way a compost containing considerable amounts of nitrogen may be prepared.

—"*Facts about Sugar,*" *October* 1935.

APPENDIX XXII

Tables containing Important Information on Sugarcane Industry in India

Table 1

Growth of the Sugar Industry in Various Provinces from 1931–32 *Pre-Protection Year to* 1944–45

Name of Province	No. of Cane Factories Working 1931–32	1944–45
United Provinces	14	68
Bihar	12	29
Punjab, Sindh N.W.F.P.	1	2
Madras	2	12
Bombay	2	10
Bengal	Nil	4
Orissa	Nil	1
Indian States	Nil	18

Table 2

Per capita *Consumption of* Gur *and Sugar in India*

Year	Sugar lbs.	Gur lbs.	Total lbs.
1931–32	6·2	17·2	23·4
1935–36	6·5	24·8	31·3
1940–41	6·7	20·6	27·3
1943–44	6·5	23·8	30·3

Table 3

Per capita *Consumption of Sugar in Various Countries*

	lbs.		lbs.
United Kingdom	106	Japan	33
U.S.A.	97	Union of S. Africa	47
Brazil	34	Netherland	64
France	52	India	27 (including 20 lbs. Gur)
Australia	116		
Germany	52		
Cuba	88		
Java	11		

Table 4

Per capita *Consumption of Sugar in the Various Provinces and States*

Name of Province	1939–40	1941–42
	lbs.	lbs.
Bengal	6·7	4·5
Madras	3·6	4·1
Bombay	15·2	19·2
Bihar (includes Orissa)	3·1	3·6
United Provinces	6·3	6·4
Punjab	12·0	13·1
C.P. and Berar	4·3	4·9
Assam	·3·5	2·4
Sind and British Baluchistan ..	14·3	17·3
Orissa	..	..
N.W.F.P.	3·8	11·1
Delhi	44·3	34·2
Rajputana	6·8	9·8
Central India	4·8	6·4
Nizam's Territory	2·8	3·2
Kashmir	1·1	2·3
Mysore	3·5	4·6

Table 5

Acreage under Sugarcane, under Improved Canes, and Average Production of Cane per Acre from 1930–31 *to* 1944–45

Year	Total acreage under cane in thousand acres	Acreage under improved canes in thousand acres	Average yield in tons per acre
1930–31 ..	2,905	817	12·3
1931–32 ..	3,076	1,170	14·1
1932–33 ..	3,425	1,845	14·9
1933–34 ..	3,422	2,295	15·3
1934–35 ..	3,602	2,433	15·1
1935–36 ..	4,154	3,056	15·3
1936–37 ..	4,582	3,452	15·6
1937–38 ..	3,869	2,968	15·5
1938–39 ..	3,130	2,673	15·0
1939–40 ..	3,640	2,893	15·0
1940–41 ..	3,598	3,480	15·0
1941–42 ..	3,515	..	15·0
1942–43 ..	3,600	..	15·0
1943–44 ..	4,234	..	..
1944–45 ..	4,134	..	..

TABLE 6

Average Yield of Cane and of Sugar in Short Tons per Acre in Different Countries

Countries	Cane tons per acre	Sugar tons per acre	Period of cane-growth
Java	45	5·5 (6·75 in 1938–39)	11–15 months
Hawaiian Island ..	45	5·5	18–24 months
Queensland	(less than) 20	2·0	2 years' crop
Cuba	20	2·0	12–15 months
Mauritius ..	20	2·0	14–20 months
Philippines ..	20	2·0	11–14 months
South Africa ..	20	2·0	2 years' crop
India	15	1·5	12–14 months

APPENDIX XXIII

FUNCTIONS AND CONSTITUTION OF THE INDIAN CENTRAL SUGARCANE COMMITTEE, 1944

The Government of India announced their decision to set up a Central Sugarcane Committee by a resolution No. F 41–24/43 A dated 6th June 1944 of the Education, Health and Lands Department.

The following is the text of the Government resolution, dated 6th June 1944, published in the *Gazette of India*:—

Taking into account of sugarcane research work and envisaging considerable further developments in the near future and the need for post-war re-adjustments, the Sugar Committee of the Imperial Council of Agricultural Research in October 1941 recommended that a Central Sugar Committee should be constituted on the lines of the Indian Central Cotton Committee and with somewhat similar powers and functions. This resolution was

endorsed by the Governing Body of the Imperial Council of Agricultural Research in July 1942. The Government of India agreeing with the Sugar Committee and the Imperial Council of Agricultural Research, have accepted this recommendation in principle and decided to set up a Central Sugarcane Committee, which will be a body corporate registered as a society under the Registration of Societies Act (XXI of 1860) with Headquarters at Delhi or such other place as the Committee may decide.

Functions

The functions of the Indian Central Sugarcane Committee will be to undertake the improvement and development of the growing, marketing and manufacture of sugarcane and its products in India and of all matters incidental thereto. This includes items such as agricultural, technological and economic research on sugarcane, gur, sugar and their by-products, the improvement of crop forecasting and statistics, the production, distribution and testing of improved varieties, the adoption of improved cultural practices, enquiries and recommendations relating to banking and transport facilities and transport routes, the maintenance of an Institute of Sugar Technology and other similar matters. The control over the Institute of Sugar Technology will vest in the Committee along the lines indicated later. The Committee will also advise the Central and Provincial Governments concerned on any points which may be referred to it by them, provided the subject-matter of the reference falls within the prescribed functions of the Committee.

Constitution

It is desirable that the growers, the manufacturers and the traders should be fairly represented on the Committee. Subject to a reserve power of nomination

by the Governor-General-in-Council so as to permit of appointments to the Committee to meet requirements that may vary from time to time, the Committee will be constituted as follows:—

1. The Vice-Chairman, Imperial Council of Agricultural Research, who will be *ex-officio* President of the Committee.
2. The Agricultural Commissioner with the Government of India.
3. The Director, Imperial Agricultural Research Institute.
4. The Director, Imperial Institute of Sugar Technology.
5. The Agricultural Marketing Adviser to the Government of India.
6. The Imperial Sugarcane Expert.

7–14. The Directors of Agriculture, Madras, Bombay, Bengal, United Provinces, The Punjab, Bihar, Mysore and Hyderabad or their nominees.

15–16. The Cane Commissioners, United Provinces and Bihar.

17–25. Nine Representatives nominated by the Indian Sugar Mills Association, of whom at least two shall be representatives of the Indian Sugar Producers Association, one representative of the Deccan Sugar Factories Association, one of the Southern Provinces Sugar Marketing Board and one of the Bengal Sugar Mills Association.

26. One Representative of Sugar Factory owners nominated by the Governor-General-in-Council.

27–30. Four Representatives of the *Gur* and Khandsari industry nominated by the Governor-General-in-Council.

31–38. Eight non-officials representing agricultural interests, one nominated by the Government of Madras, one by the Government of Bengal, two by the Government of United Provinces, one by the Government of Punjab, one by the Government of Bihar and two by the Governor-General-in-Council, to represent other areas.

39–41. Three Representatives of Sugar Trade—one nominated by the Bombay Sugar Merchants' Association, one by the Cawnpore Sugar Merchants' Association and one by the Indian Sugar Syndicate.

42–44. Three Representatives nominated by the Governor-General-in-Council to represent the consumers.

45. One Representative of Sugar Technologists nominated by the Governor-General-in-Council.

The tenure of the appointment of the members of the Committee other than those who are appointed by reason of the office or appointment they hold, will be three years with effect from the 1st April of the year in which they are appointed or such lesser period as may be specified in the notification.

The Secretary of the Committee, who will not be a member of it, will be appointed by the Governor-General-in-Council, but he will be paid from the funds of the Committee. The Director of the Institute of Sugar Technology will continue to be a servant of the Government of India. His salary and allowances will also be paid from the funds of the Committee, but the Government of India have agreed to meet his leave and pension contribution. The Committee will continue to employ at the Institute of Sugar Technology from its own funds such staff as has been lent to the Institute

by the Government of the United Provinces on the same basis on which they are at present employed by the Government of India, as also such other staff as are at present on contract till such time as contracts expire.

The Committee will continue to maintain the Imperial Institute of Sugar Technology both as a teaching and as a research institution and will be responsible for the maintenance of sugar standards. Returns under the Sugar Production Rules, the maintenance of sugar trade information services any special work that may be required by the Central or by any Provincial Government will be directly under the control of the Director of Institute of Sugar Technology.

Funds of the Committee

The Government of India will finance the Committee by placing at its disposal the entire proceeds of the Sugar Excise Fund; the amount so credited shall continue to be one anna per cwt. of white sugar produced in British India out of the excise duty levied on it. The question of increasing this amount will be considered after the war. If the amount placed in the fund in any year falls short of the needs of the Committee, the Government of India will automatically grant a loan free of interest to cover the deficit and enable the Committee to incur expenditure upto a limit of Rs. 11·75 lakhs in the year subject to the condition that the first charge on any surplus occurring thereafter will be the repayment of this loan. The Committee will meet all the present liabilities of the Fund and take over all its assets.

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